PRACTICAL EXERCISES IN CHEMISTRY

G. C. DONINGTON M.A.

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PRACTICAL EXERCISES IN CHEMISTRY

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PRACTICAL EXERCISES IN CHEMISTRY

BY

G. C. DONINGTON, M.A.
SENIOR SCIENCE MASTER OF LEEDS GRAMMAR SCHOOL

MACMILLAN AND CO., LIMITED
ST. MARTIN'S STREET, LONDON
1907

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First Edition 1906.
Reprinted 1907.

GLASGOW: PRINTED AT THE UNIVERSITY PRESS
BY ROBERT MACLEHOSE AND CO. LTD.

PREFACE.

It is now recognized by teachers of chemistry that the best way to inculcate the elementary facts and principles of the subject in the case of young students is to set them to perform, in the laboratory, a series of simple experimental researches bound together in a logical sequence; and to leave the students to make their own observations and to draw their own conclusions. To encourage this self-activity on the part of the pupils as much as possible, it has become customary in many laboratories to forbid the introduction of text-books during the practical lessons.

There is much to be advanced, on theoretical grounds, in favour of this plan. In practice, however, a strict observance of the rule generally leads to one of two undesirable results. Either the time available for practical work is heavily discounted, since a large part of the period is absorbed by the teacher in explaining the nature and object of the experiment and in making manipulative details clear; or sheets of instructions, prepared by the teacher in his too scanty leisure hours, are introduced. Both practices can, the author thinks, be avoided by the use of a book which provides clear directions for carrying out the selected experiments, but avoids any statement as to the precise facts to be observed, and leaves entirely to the student the work of making deductions

The present book has been prepared upon these lines. The instructions have been made as explicit as possible; the results to be expected in any exercise are mentioned only in those cases where they are essential to the sequence of ideas in succeeding work; and careful guidance is provided for the statement of numerical results and calculations. The volume may be regarded, in fact, as an attempt to secure the advantages of modern "research" methods of study and yet to recognize the actual conditions of class teaching in school laboratories.

The elements of non-metallic chemistry and of chemical theory—so far as they can be studied in ordinary secondary schools—are dealt with, and though the book follows no syllabus slavishly, its scope may be defined by pointing out that all the subjects included in the new syllabus in chemistry for the Matriculation Examination of the University of London are to be found here.

Several of the experiments are perhaps more suitable for demonstration by the teacher than as exercises for the pupil; others, again, are too difficult for students working through the course for the first time. All these exercises are indicated by asterisks. With younger students it will probably prove advisable to take Chapters V. and VIII. before Chapters IV., VI., and VII., but the order of treatment will vary, of necessity, with the circumstances of the school.

It is presumed throughout that careful notes will be insisted upon by the teacher. These, of course, should be written immediately after the completion of the experiments, and it is to assist the pupil in this work that the questions, which often conclude the directions for an experiment, have been provided.

The author feels the impossibility of expressing adequately his indebtedness to the teaching of Prof. H. E. Armstrong, in whose laboratories at the City and Guilds' Central Technical College he was privileged to work for two years. He wishes also to record his gratitude for the great assistance given by Dr. T. M. Lowry and Messrs. G. M'Farlane and R. Stockdale in reading proof sheets and in other ways. His warmest thanks are due, too, to Prof. R. A. Gregory and Mr. A. T. Simmons, without whose help and advice—ungrudgingly given—this book would never have been written.

G. C. DONINGTON.

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HIGH SCHOOL,
BANGALORE.
ESTABLISHED
SEPTEMBER 1873.

PRACTICAL EXERCISES IN CHEMISTRY.

CHAPTER I.

INTRODUCTORY.

1. The Fishtail Burner.

(*a*) Obtain a fishtail burner and examine it. Turn on the gas and light it. Sketch the flame in your notebook.

(*b*) Hold a porcelain basin in the flame for a moment and see what effect is produced on the basin.

(*c*) Take a piece of iron wire (No. 20) about four inches long and hold it with crucible tongs in different parts of the flame: (i) just above the top of the burner, (ii) in the centre of, and (iii) at the top of the flame.

Observe carefully what happens in each case, and write down what you observe in your notebook. Decide which are the hotter and cooler parts of the flame.

> In every case where an experiment is carried out, or an observation made, a record of what is done or seen should be made *at once* in the notebook. When any special apparatus is used, a diagram of it should be drawn.

2. The Bunsen Burner.

(*a*) Examine your Bunsen burner and make a sketch of it. Mark on your sketch the tube through which the gas enters the burner, and the air-holes.

(*b*) Close the air-holes and light the gas. Compare the flame produced in these circumstances with that of the fishtail burner. Hold a piece of porcelain in the flame and note what happens.

(*c*) Open the air-holes gradually and observe any changes in the flame. Sketch the flame as it appears when the air-holes are open. Using a piece of iron wire, find which are the hotter and cooler parts of the flame, and mark them on your sketch. Does this flame leave any soot on a piece of porcelain when it is held in it?

(*d*) Take a match (an ordinary wax vesta is best) and stick a pin through it at right angles as near the head as possible. Turn off the gas and hang the match at the opening of the tube of the Bunsen burner, so that the match is in the middle of, and the head projects above, the tube (Fig. 1). Turn the gas on full and light it again. Does the match catch fire at once? Remove the match and with the crucible tongs hold a short glass tube slanting upwards, with one end in the inner part of the flame, where the match head was hung. Bring a lighted match to the other end of the glass tube. Decide what the inner part of the flame contains

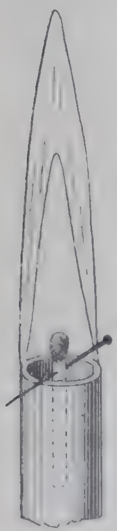

FIG. 1.—Match in centre of Bunsen flame.

(*e*) When you have removed the tube, light the flame again, leaving the air-holes open. Turn the gas off gradually until the flame is not quite out and note what happens. Do you observe any smell? Take care not to touch the tube: it will soon be very hot. Turn the gas on full. Does the flame go back to its original position?

NOTE.—This "striking back" of the flame is always a source of danger in burners in which a mixture of gas and air is used. The rubber tube connecting the burner with the gas supply may become heated until it melts and allows the gas to escape or even to burn at the leak thus formed.

When the lighted burner is not in use for any length of time, the air-holes should be closed and the flame turned as low as possible.

3. The Fletcher Burner.

(*a*) Sketch a Fletcher burner; note the air-hole. Attach the burner to your gas tap and light the gas.

(*b*) Write down three points in which this form differs from the Bunsen burner. For what purposes is a Fletcher burner specially suited?

(*c*) Find which are the hotter and cooler parts of the flame. Does this flame give a deposit of soot?

4. Making a Stirring Rod.

(*a*) From a length of glass rod cut a piece 15 cm. long. For this purpose use a triangular file, and with it make a single scratch at the place where the rod is to be cut: do not *saw* the glass or try to make a deep groove. Now hold the glass with the scratch away from you, placing your hands on either side of the scratch and your thumbs inwards opposite the scratch (Fig. 2). Pull the ends of the rod as if to stretch it, at the same time pressing outwards

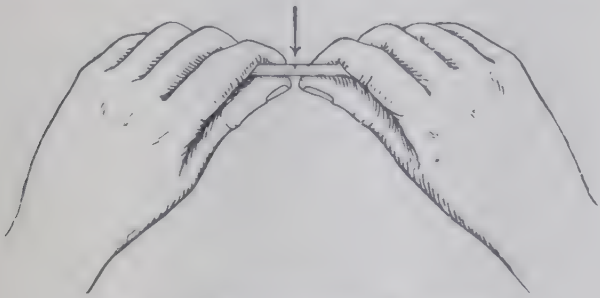

FIG. 2.—Breaking a piece of glass rod.

slightly with the thumbs. If the glass does not yield with gentle pressure, make a second scratch at the same place and repeat the pulling process. The glass should then break with a perfectly clean edge.

(*b*) Hold the end of the rod in the hottest part of the flame of a Bunsen or Fletcher burner, and rotate it between your thumb and next finger until the sharp edges have become rounded. Do the same with the other end of the rod.

5. Bending a Glass Tube.

(*a*) From a piece of glass tubing cut a piece 20 cm. long, in the same way as you cut the rod in Ex. 4 (*a*).

(*b*) Clean the tube in the following way. Unravel the strands of a piece of string near the middle, and insert a piece of cotton wool between the strands. Thread the string through the tube, and pull the wool backwards and forwards through the tube until it is clean.

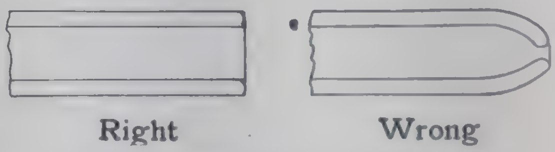

FIG. 3.—Rounding the end of a glass tube.

(*c*) In order to get rid of the sharp edges of the tube, rotate its ends in the hot part of a Bunsen or Fletcher flame: do not hold it too long in the flame or the edges will bend inwards (Fig. 3).

(*d*) Hold the tube lengthwise in the hot part of the flame of a fishtail burner having a hand at each end, and slowly turn the tube so as to heat it uniformly all round. More than 5 cm. length of the tube should be heated at the same time by using the full length of the fishtail flame. When the tube becomes soft, take it from the flame and make a right-angled bend. If you have heated a sufficient length of the tube you should now have an even bend, as in Fig. 4*a*. If a Bunsen burner is used for bending a tube, only a short length of the tube is heated and the glass becomes folded in, as in Fig. 4*b*.

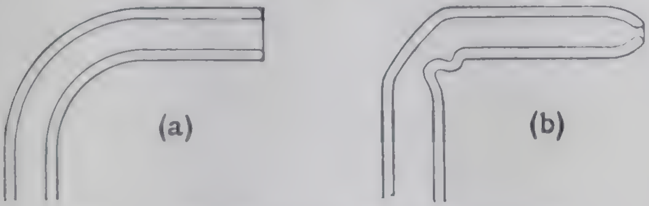

FIG. 4.—Bending a glass tube at right angles.

6. The Blowpipe.

(*a*) Examine a simple mouth blowpipe. Hold a small fragment of charcoal by means of crucible tongs, in the hottest part of a Bunsen flame. Rest the short tube of the blowpipe on the top of the Bunsen burner and, blowing gently, direct the flame on to the piece of charcoal. Is the charcoal hotter now than when you held it in the original flame?

(*b*) Obtain a Fletcher blowpipe with bellows attached. Sketch the burner and mark on your sketch the entrances for gas and air. Find out to which part of the jet these tubes lead, and also mark on your sketch the point at which the gas and air are brought together.

(*c*) Turn the gas half on and light it. Find out if the flame gives soot. Compare this flame with the flame of a fishtail burner and that of a Bunsen burner with air holes closed. Is there any difference between them?

(*d*) Turn the gas on full and begin to work the bellows, gradually putting on the full pressure of air. Note any changes in the flame and find out whether any parts of the flame are hotter than others.

(*e*) In order to compare the heat given by the Bunsen flame with that of the blowpipe flame, hold a piece of charcoal by means of the crucible tongs (i) in the hottest part of the Bunsen flame, (ii) in the blowpipe flame with the gas not fully turned on and a good supply of air. Record exactly what happens.

7. Making a Glass Jet.

(*a*) From a piece of glass tubing (5 mm. in diameter) cut a piece 10 cm. long.

(*b*) Clean the tube and round the ends.

(*c*) Heat the middle of the tube in a small pointed blowpipe flame, twirling the tube continually in order that it may be heated evenly all round. When it is quite soft, take the tube from the flame and draw it out, at first slowly, then more rapidly, and hold it stretched out until the glass has become stiff. While drawing out the tube, slightly turn your hands in opposite directions: this plan will help to keep the drawn-out tube round. After scratching it with a file, break the drawn-out tube at such places as will leave two jets, one of them coarse and the other fine (Fig. 5*a*).

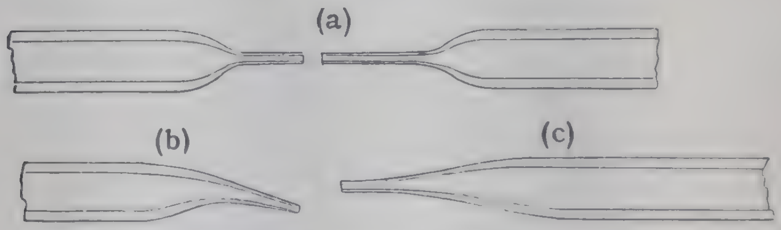

FIG. 5.—Making a glass jet.

If the tube is not heated evenly it will draw out on one side as shown in Fig. 5*c*, and if after being drawn out in the flame it is not held out till rigid, it will droop as in Fig. 5*b*.

8. Fitting up a Wash Bottle.

(*a*) Procure a flask holding about a litre. If it is dirty clean it in the following way.

(i) Rinse it with several small quantities of water, keeping one hand on the tap and turning off the water as soon as you have taken what is needed: do not fill the flask with water or allow the water from the tap to run to waste down the sink.

(ii) If the flask is still dirty, the neck may be cleaned by means of a brush or a bunch of cotton waste tied on the end of a stick, or a *few drops* of hydrochloric acid may be poured into the flask and allowed to flow over the surface: the flask should then be rinsed 3 or 4 times with small quantities of water.

> NOTE.—The final rinsing should be with distilled water. See Ex. 27.

(iii) The flask may then be allowed to drain, and may be dried by blowing hot air through it. For this purpose fit an iron tube with corks and short glass tubes at each end. Heat the iron tube and pass air through it by means of the bellows.

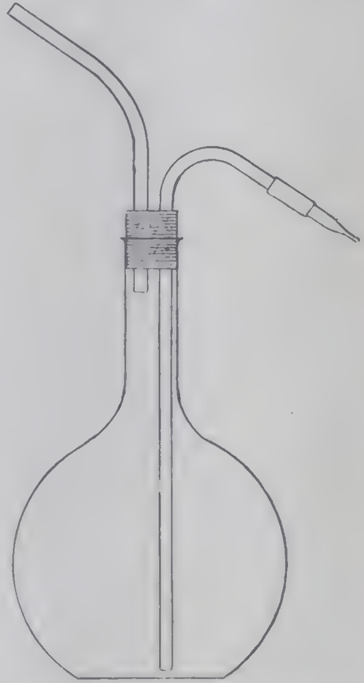

FIG. 6.—Flask fitted for use as wash bottle.

(*b*) Cut two pieces of glass tube (5 mm. in diameter), one of them 15 cm. long, the other long enough to reach to the bottom of the flask and to project above the mouth about 10 cm. Clean the tubes and round their ends as directed in Exs. 5 (*b*) and (*c*).

(*c*) Bend the tubes you have prepared to the shapes shown in Fig. 6, so that when the tubes are fitted together in the wash bottle the shorter arms are in a straight line with one another (Fig. 6).

(*d*) Select a sound cork, just too large to fit the flask; wrap a piece of paper round it and soften it by rolling it on the floor with your foot until it fits the flask. Obtain a cork-borer one size smaller than the tubing you have cut, and with it bore two holes in the selected cork. Start to bore the cork from its narrow end, and be careful to pause as soon as the borer is well into the cork, in order to see if you are boring straight. When the borer is nearly through, pull it gently out and start to bore again from the other end, so that the two holes meet: this will prevent tearing the cork in boring. A sharply pointed rat-tail file may be used instead of a cork-borer: push the point into the cork and drive the file through with a twisting motion until a sufficiently large hole has been made.

(*e*) Fit up the wash bottle as shown in Fig. 6, attaching one of the jets you have made to the longer piece of bent tube by means of a piece of rubber tubing not more than 3 cm. long.

(*f*) Stand the wash bottle on a piece of felt or house-flannel 6 inches square. If the flask is allowed to stand directly on the bench, it may be scratched by grit, and will then become liable to break when heated.

9. Wire Gauze.

(*a*) Hold a piece of iron wire gauze above the Bunsen flame and gradually lower the gauze until it almost touches the top of the burner. What happens?

(*b*) Repeat Ex. 9 (*a*) using copper gauze. Is any difference to be observed?

(*c*) Turn out the gas, put the gauze on to the top of the burner, turn on the gas, and light it. Slowly raise the gauze. What happens? Place the gauze on the top of the tube and gradually lower the flame, until it disappears. Compare this result with what you have previously seen [Ex. 2 (*e*)].

(*d*) Make a safety Bunsen by fastening a sq. inch of iron gauze over the tube of your Bunsen burner.

ADDITIONAL EXERCISES. I.

1. Examine and sketch a candle flame. Does the flame leave soot on a piece of cold porcelain held in it? Procure a short glass tube with open ends. Hold the tube with one end in the inner blue part of the candle flame, and the upper end slanting away from the flame. Bring a lighted match to the upper end, and thus discover whether the gas which issues will burn.

2. Seal a glass tube in the following manner. Obtain a tube about 1 cm. in diameter and 15 cm. long. Heat it in a pointed blowpipe flame and draw it out as directed in Exercise 7 (*c*). Cut the tube at its narrowest point. Heat one of drawn out ends until it closes. Remove it from the flame and blow gently into it so as to force out the closed end to a round shape. If necessary heat it again and repeat the blowing.

CHAPTER II.

THE MEASUREMENT OF VOLUME AND CAPACITY.

10. The Unit of Volume.

(*a*) Cut from a piece of soap a cube with edges 1 cm. long.

The volume of this cube is called a **cubic centimetre**.

(*b*) Measure the length in centimetres of the twelve edges of a metal cube. Calculate the average length of an edge and hence the volume of the cube.

(*c*) Obtain a rectangular block of wood, measure the length of the edges, and hence calculate the volume in cubic centimetres by multiplying the three length measurements together.

11. The Unit of Capacity.

(*a*) On an unused sheet of thin cardboard mark out five squares with sides 1 decimetre long, arranging them in the form of a cross as shown in Fig. 7. Cut out the part of the cardboard that you have marked and fold it into a cube, fastening the edges together with pieces of stamp paper. The box you have made has a capacity of 1 cubic decimetre; that is, if made water-tight, it would hold exactly a cubic decimetre of liquid. For measuring the volumes of liquids, vessels of known capacities are employed.

The cubic decimetre is called a **litre**.

(*b*) Write in your notebook how many cubic centimetres there are in a litre.

(*c*) Fill a litre flask with water up to the mark on the neck. Let the lowest part of the curved surface of the water be level with the mark, and be careful to keep your eye at the same level as the mark while judging the height of the surface. If you are looking at the flask in the right way, the circular mark appears as a straight line.

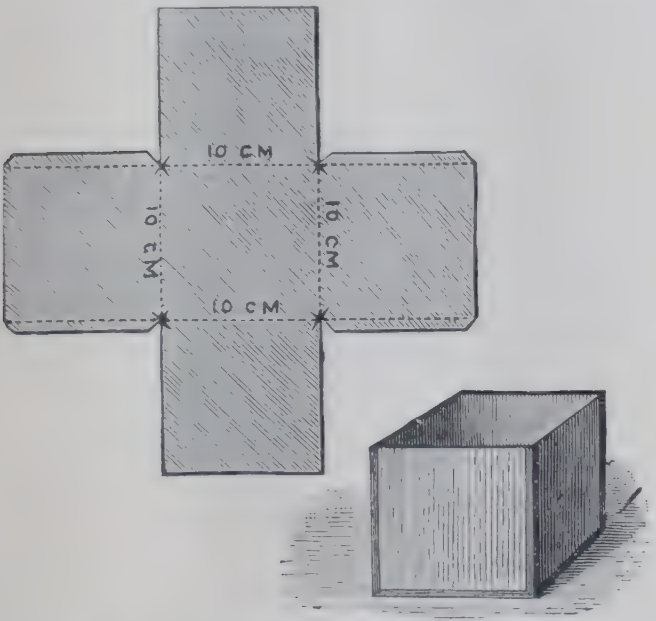

FIG. 7.—Construction of box to hold 1 litre.

If the flask has been correctly graduated, it will now *contain* a litre of water.

(*d*) Pour the litre of water into vessels of different shapes, so as to become familiar with this amount of water. Notice, however, that a certain amount of water always remains clinging to the walls of the flask; the flask, therefore, *delivers* rather less than a litre of water.

Some flasks are graduated so as to *deliver* a litre of water, and therefore contain rather more than a litre.

(*e*) Procure a large biscuit tin and measure its *internal* length, width, and depth in centimetres. Calculate its capacity in litres. Then fill it with water from a litre flask, and find how many litres of water it will hold.

12. Exercises on Capacity.

(*a*) Procure a measuring cylinder and write down

(i) the capacity in cubic centimetres of the graduated part of the cylinder, and

(ii) the number of c.c. corresponding to each graduation.

(*b*) Fill the measuring cylinder with water to the level of the highest graduation. As the cylinder is so much wider than the neck of a flask the volume of water cannot be adjusted so exactly, and great care must be taken to get the lowest part of the surface of the water on a level with the graduation. Care must also be taken that the cylinder is standing straight: for this purpose either place it on a level table, or hold the top of the cylinder between your thumb and second finger so that it hangs freely in a vertical position.

(*c*) Fill a dry litre flask with water by means of the cylinder, and note the exact number of c.c. required.

(*d*) Procure a number of flasks, beakers, bottles, etc. Guess the number of c.c. that each will hold, and then measure its capacity by pouring in water from the measuring cylinder and so find how nearly you are right in your estimate.

13. Experiments with the Burette.

(*a*) Procure a burette and write down the volume corresponding to one of its small graduations and the whole volume of the burette.

(*b*) Fill the burette with water and empty it again. Notice if any drops remain on the sides of the burette; if so, the burette is greasy and must be cleaned before it can be used.

Procure a thin cane (similar to those used for caning chairs), split one end and insert a small piece of cotton waste; wind the waste round the cane, and fasten the end in the split. Pour a few c.c. of caustic soda solution into the burette and thoroughly rub the inside of the burette with the cleaner. Rinse the burette repeatedly with small quantities of water. If the burette is still greasy, rub it again with soda until it is quite free from grease.

(*c*) Fix the burette in a clamp and see whether it is exactly perpendicular. This course should always be adopted before any measurements are taken with the burette. Fill it with water, hold a piece of white paper behind the liquid, examine the surface of the water, and sketch what you see.

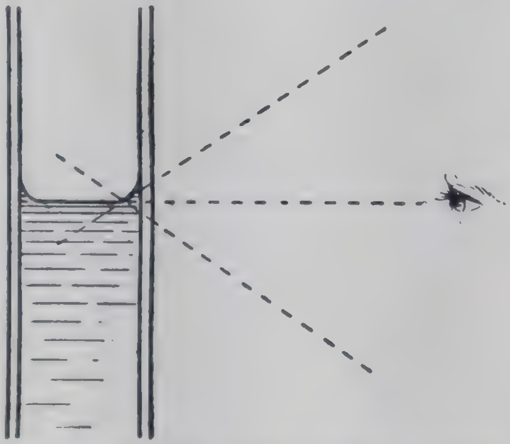

FIG. 8.—Showing the correct method of reading the volume of liquid in a burette.

(*d*) Run the water from the burette until the lowest part of the curved surface is exactly level with the top graduation; in judging the height of the liquid in the burette you must be careful to keep your eye level with the surface of the water, as in Fig. 8. If your eye is higher than the surface of the water, the number you read will be too low, if it is lower the reading will be too high. In some burettes the graduations are carried round to the other side of the burette, and the reading can then be taken as accurately as in the case of a litre flask. A good way to read an ordinary burette is to place a small mirror behind it, and to see that the surface and its image in the mirror appear level when the reading is taken.

(*e*) Run a few c.c. of water from the burette, and take the reading after allowing a few seconds for the water to drain down the sides of the burette. Repeat this several times. The burette must be read to half a graduation, and with practice may be read to within a hundredth of a c.c.

A burette is therefore a very accurate instrument for delivering small quantities of liquid.

(*f*) Run out 20 drops from the burette and note the reading before and after. Repeat this three times. Calculate the average volume of a drop from the burette. Write these results down in the following manner:

Volume of 20 drops = ...c.c.
∴ Volume of 1 drop = ...c.c.

(*g*) Procure a flask which is graduated to contain 100 c.c. Fill the flask from the burette and notice the exact volume of water required: as the burette *delivers* 50 c.c. and the flask *contains* 100 c.c., the two volumes should agree if the graduations are correct.

* (*h*)[1] Obtain a small test-tube and, if necessary, clean it with soda. Fix a narrow strip of gummed paper down the outside length of the test-tube, and run into it from the burette successive quantities of 5 c.c. of water, marking on the paper the level of the surface at each addition. Measure with a scale the distance between each of the marks and divide each of them into 5 or 10 equal parts by smaller graduations. You can now use the test tube as a small measuring cylinder in future experiments.

(*i*) By a similar method graduate for yourself a small flask. Mark on the neck the level of the liquid after you have run in 200, 250, or 300 c.c. of water from the burette.

---

[1] Experiments marked * may be omitted in working through the book for the first time.

The flask must be of such a size that one of these volumes of liquid fills it to some point on the neck. The mark is best made with a strip of gummed paper and a small file-mark to indicate the position in case the paper should be washed off. Keep the flask for use in later experiments.

14. Experiments with a Pipette.

(*a*) Procure a pipette which is graduated to deliver 25 c.c. Hold it between your thumb and three fingers (Fig. 9), leaving the first or index finger free. Draw water into the pipette with the mouth, until its level is above the graduation in the tube. Slip the first finger quickly on to the end of the tube, and hold it there so tightly that no water can run out. Raise the mark to the level of your eye, so that the surface of the water appears as a straight line; then release the pressure of your finger and let the water run out, drop by drop, until the lowest part of the surface of the water is level with the mark. Now remove your finger, and let the water run into a flask, or beaker. Let the pipette drain for a few seconds, and then touch its point against the side of the vessel into which you are delivering the water; but do *not* blow out the drop which remains in the pipette.

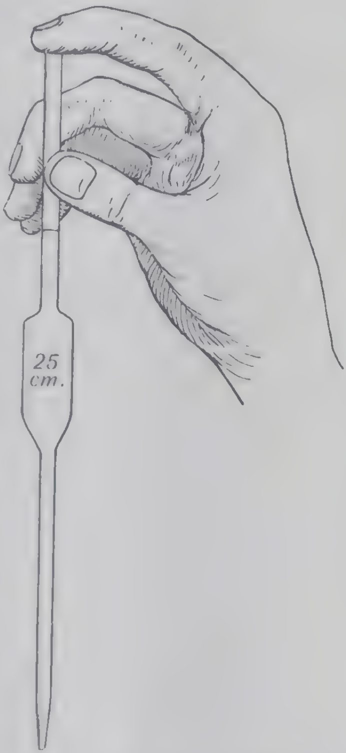

FIG. 9.—The use of a pipette.

(*b*) Fill a 100 c.c. measuring flask with water from the 25 c.c. pipette and notice whether the level of the liquid in the flask coincides with the graduation. If it does not, repeat the exercise and see whether you have been wrongly using the pipette. If you obtain the same result the second time, the graduations themselves may be incorrect.

15. Volumes of Solids by Displacement.

(*a*) Half fill a 100 c.c. measuring jar with water and make a note of the exact height of the water. Attach a thin piece of cotton to a glass stopper; tilt the cylinder and gently slide the stopper down the jar. Find how much the level of the water has risen: this rise will give the volume of the stopper. Record your results thus:

Reading after sliding in the stopper = ...c.c.
Reading before sliding in the stopper = ...c.c.
Volume of stopper = ...c.c.

(*b*) Fill a 50 c.c. burette up to about the 50 c.c. mark with water. Make a note of the exact volume and slide into the water a small roll of sheet lead; calculate the volume of water displaced. Record your results as in the last exercise.

*(*c*) Into a litre measuring cylinder pour about 500 c.c. of water, and find the increase in volume when several small marbles or pebbles are put in, and hence determine their total volume.

*(*d*) Using the test-tube graduated in Ex. 13 (*h*), count the number of lead shot required to raise the level of the water 5 c.c., and hence calculate the average volume of the single shot, as you would calculate the average of several scores at cricket.

(*e*) Procure a rectangular block of wood and determine its volume: first, by measurement with a ruler; and secondly, by finding the volume of water it displaces when pressed beneath the surface of water in a graduated cylinder with a hat-pin or piece of wire.

(*f*) Find in a similar way the volume of a piece of wood of irregular shape, tying to it a piece of lead in order to sink it beneath the water.

ADDITIONAL EXERCISES. II.

1. Obtain a prism of wood, or glass, with triangular end. Find the area of the triangular end. Hence calculate the volume of the prism.

2. Measure the diameter of a cylinder of wood or metal. Hence calculate the area of the end and the volume of the cylinder.

3. Find the internal diameter of a glass tube, and hence calculate the circular area of the end of the tube. Next calculate how much water a 5 cm. length of the tube would hold. Verify this by filling a certain length of the tube with water and measuring its volume.

4. Determine by means of a burette the total volume of a piece of fine wire. Calculate its volume per unit of length.

5. Determine, by measuring length and volume, the area of section of a piece of wire.

6. Ascertain the volume of a cork.

7. Measure the internal and external diameter of a glass tube. From these figures calculate the volume of glass in the tube for every cm. of its length. Verify the result by finding the volume of water displaced by the whole tube.

8. Procure a jar graduated in fluid ounces. Use it to find the number of c.c. in a fluid ounce.

9. Find the number of c.c. in a pint. Hence calculate the number of litres in 1 gallon, and the number of pints in 1 litre.

CHAPTER III.

THE BALANCE AND ITS USE.

16. The Balance.

(*a*) Examine carefully the balance provided for your use. Make sketches in your notebook of

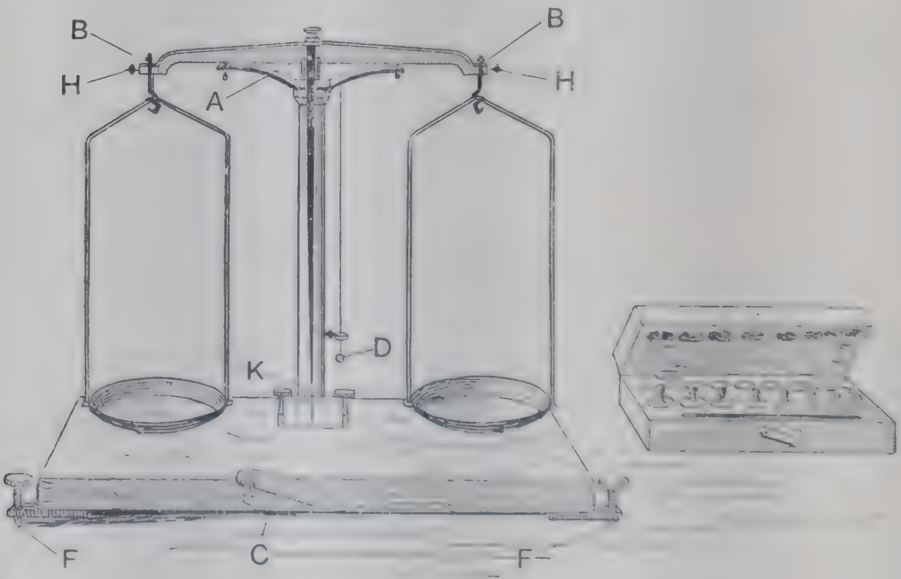

FIG. 10.—Balance and box of weights.

(i) the central knife-edge (Fig. 10, *A*) and the plane on which it rests;

(ii) the knife-edges (Fig. 10, *B* and *B*) and the planes on which the pan-supports hang.

(*l*) Write answers to the following questions:

(i) Why must the pans and the beam never be touched when the releasing lever (Fig. 10, *C*) has been turned and the central knife-edge is resting on its plane?

(ii) How can you tell when the balance stand is not level and how can you level it?

(iii) Sometimes the beam is heavier at one end than the other and is therefore not swinging equally. How can you remedy this defect?

17. The Metric System of Weights.

(*a*) Open your box of weights and take from it the weight with 1 stamped on it. This weight is called a *gram*. Find out by actually weighing, if you can do it in no other way, what number of grams, or parts of a gram, there are in the other weights in your box; and make a list of them.

(*b*) Try to think of some number of grams between 1 and 100, for which you cannot find the right weights in your box.

(*c*) Pick out weights to make up 113·00 grams, 79·50 grams, 33·30 grams, 57·80 grams, 6·02 grams and 0·78 grams. Lift the weights by means of the forceps provided.

> In weighing larger objects the unit of weight generally taken is the kilogram, which is equal to 1000 grams, or about 2¼ lbs. One thousand kilograms are nearly equal to an English ton. Special names are also used for fractions of a gram as follows:
>
> 0·1 gram = 1 decigram
> 0·01 gram = 1 centigram
> 0·001 gram = 1 milligram.

(*d*) Fill in the blanks in the following table:

10 grams = ……kilogram
10 grams = ……decigram
1 decigram = ……milligrams
1 milligram = ……centigram.

18. A Suitable Tray for the Small Weights

* (*a*) Take a piece of stiff paper 10 cms. long and 5 cms. wide and rule off a margin 1 cm. wide on three of the sides (Fig. 11). Divide the remaining space (marked *F*, *K*, *M*, *H* in Fig. 11) into squares with sides 2 cms. long, and write figures in the squares to correspond to the small weights in your box (*i.e.* those less than 1 gram). Cut along the lines marked *AF*, *BF*, *CH*, and *DH* in Fig. 11 with a sharp knife and bend up the 1 cm. margins. Join together the corners at *F* and *H* with pieces of gummed paper. You have now made a tray with a raised edge on three sides. Take the weights below 1 gram from the box and put them in the places thus prepared for them; they should always be kept in the tray while in use, since the raised edge prevents them being lost.

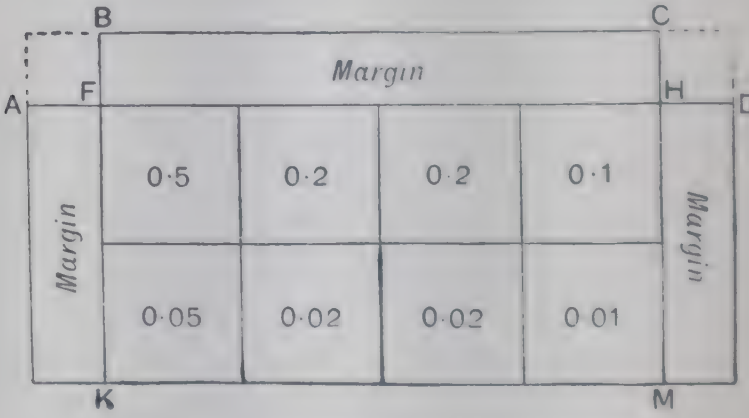

FIG. 11.—Construction of tray for small weights

19. The Use of the Balance.

(*a*) Examine the balance to see if the plumb line (Fig. 10, *P*) is hanging exactly in the centre of the ring. If not, turn the levelling screws (Fig. 10, *L*, *L*) at the corners of the stand until the balance is perfectly level.

(*b*) Turn the lever so that the beam is raised from its supports, and set it swinging by gently wafting air into a pan with your hand. Is the pointer swinging over an equal number of divisions on each side of the centre division of the scale? If not, screw the adjusting screws at the end of the beam (Fig. 10, *H*, *H*) in or out, as required, until the beam swings evenly. The balance is now ready for use.

(*c*) In order to check the accuracy of the weights and balance, place the two 10-gram weights one in each pan. Do they balance each other? If not, either one weight is heavier than the other, or one arm of the balance is longer than the other. Investigate this alternative by placing the weights in opposite pans. If the same pan is still the heavier, the fault is in the balance; if the opposite pan is now the heavier, the weights are inaccurate.

Repeat this experiment with another pair of weights from the box.

(*d*) As a simple exercise in weighing, place a penny in the left-hand pan. Select the weight which you think will just balance it, and with the forceps place it in the right-hand pan. (Weights must never be touched with the fingers.)

Raise the lever very slightly until you can see whether the weight is too heavy or too light, and then *gently* lower it again. If the weight is too heavy, replace it with another, until you have the weight which is just too light to balance the coin. Add the next smaller one; if that makes the weights too heavy, put on a lighter one instead. When the weight is nearly correct, set the beam swinging and notice over how many divisions of the scale the pointer moves on either side of the centre of the scale. Alter the weights until the pointer swings evenly. Now write down in your notebook the weights that have been taken from the box and tray and add them up. (After a little practice, you will be able to find the total without writing down each weight separately.) Next put the weights back into tray and box, counting them as you move them. See if the two calculations agree. If they do not, you must repeat the weighing.

(*e*) When you have found the weight of one penny, weigh four pennies at once, and find the average weight of one. Does this result agree with the weight you found before?

*(*f*) Weigh 20 lead shot and calculate the average weight of one shot.

ADDITIONAL EXERCISES. III.

1. Procure an ounce weight and find its weight in grams. Calculate the number of grams in a pound and of lbs. in a kilogram (correct to the third decimal place.)

2. Find the area of a piece of sheet lead. Weigh it and calculate the average weight per square inch.

3. Place a piece of glass (*e.g.* a stopper) in one pan of the balance and put small shot into the other pan, until the pans are in equilibrium. Remove the glass and put weights in its place until equilibrium is again restored. Hence write down the weight of the glass.

A substance used like the shot in this exercise is called a *counterpoise*. Observe that by this method a correct result can be obtained even with an incorrect balance.

4. Find the length and weight of about 10 cm. of iron wire. Calculate the weight of 1 cm. of the wire.

CHAPTER IV.

THE DENSITY OF SOLIDS AND LIQUIDS.

20. Density of Regular Solids.

(*a*) Weigh any cube of metal. Measure the length of several edges and thus find the average length of an edge. Calculate from the length of the edges the volume of the cube. From these numbers find the weight in grams of a cubic centimetre of the metal. Express your results as follows:

Weight of cube = ... grams
Volume of cube = ... c.c.
∴ weight of 1 c.c. of metal = ... grams

The **weight of unit volume** of a material affords a measure of its **density** *i.e.* of the *mass*, or amount of "stuff," contained in unit space.

(*b*) In a similar manner determine the density of a rectangular block of wood.

21. Density of Irregular Solids.

(*a*) Weigh a pebble. Find its volume by the method of Exercise 15 (*a*). Hence calculate its density, stating your results in the way shown in Exercise 20 (*a*).

(*b*) In a similar manner find the density of a glass stopper. If possible use the one the volume of which you measured in Exercise 15 (*a*).

(*c*) Weigh the piece of lead used in Exercise 15 (*b*). From your knowledge of its volume, calculate the density of the lead.

* (*d*) Calculate the density of the lead shot used in Exercise 15 (*d*). Compare this result with the value found in the last section.

22. The Density of Water.

(*a*) Clean and dry a flask which contains about 200 c.c. Find its weight. Measure 100 c.c. of water into the flask by means of a burette. Weigh the flask and water together. Find the weight of the water, and hence calculate the weight of 1 c.c. Enter your weighings thus:

Weight of flask and 100 c.c. of water = ... grams
Weight of flask alone = ... grams
∴ weight of 100 c.c. of water = ... grams
∴ weight of 1 c.c. of water = ... grams

* (*b*) Dry and weigh a measuring flask which holds 100 c.c. In drying this flask take great care not to crack it. Instead of heating the flask itself, blow warm air into it. For this purpose attach a piece of iron tubing to the rubber tube from the bellows. Fit each end of the iron tube with corks through which pass smaller glass tubes. To one of these glass tubes connect the bellows tubing; to the other a glass tube long enough to reach to the bottom of the flask to be dried. Heat the iron tube over a Fletcher burner. When it is sufficiently hot, blow air through it into the flask.

Having thus dried the flask, let it cool, and weigh it. Fill it with water up to the mark and weigh again. From these numbers calculate the density of water. Compare this result with that obtained in the last exercise.

At the ordinary temperature of the room a litre of water weighs 998 grams.

* (*c*) Since the flask used in the previous exercise may not be correctly graduated, calculate, from the weight of water contained by it, its true volume, assuming that 1 litre of water weighs 998 grams.

* (*d*) In a similar way calculate the volume of water delivered by your burette for every c.c. graduation.

23. Relative Density of Liquids.

(*a*) Procure a *Density Bottle* and sketch it. Fill it to the brim with water and replace the stopper. Observe the means by which the excess of water escapes. Notice that the water level adjusts itself. Write your reasons for thinking this an accurate method of obtaining a given volume of a liquid. Compare its use in point of accuracy with the use of a graduated flask, and a pipette for the same purpose.

Some density bottles (Fig. 12) have a narrow groove cut in the side of the stopper by means of a file. Others are made with stoppers pierced with a tiny hole which allows the excess of water to pass out. The volume of liquid can thus be adjusted much more accurately than when a measuring flask is used.

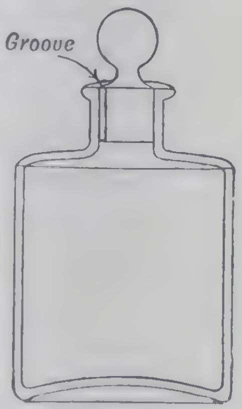

FIG. 12.—Density bottle.

> **The weight of a given volume of liquid divided by the weight of an equal volume of water** gives a number which is called the **Relative Density**. The relative density of liquids may most easily be found by means of a density bottle.

(*b*) Dry the density bottle carefully and weigh it. Fill it with water, taking care that no bubbles of air are left inside. Dry the outside of the bottle and weigh it again. Calculate the weight of water held by the bottle. Pour out the water and again dry the interior of the bottle. Fill it with methylated spirit and again weigh. Finally calculate the relative density of spirit. Record your results as follows:

Weight of bottle and water = ... grams
Weight of bottle = ... grams
∴ weight of water = ... grams

Weight of bottle and spirit = ... grams
Weight of bottle = ... grams
∴ weight of spirit = ... grams

$$\therefore \text{ relative density of spirit} = \frac{\text{weight of spirit}}{\text{weight of water}} = \ldots\ldots$$

(*c*) Finally, from the number which you obtained in Ex. 22 for the density of water, calculate the density of spirit as follows:

1 c.c. of water weighs ...... grams
But relative density of spirit = ...
∴ 1 c.c. of spirit weighs ...... grams

24. Relative Density of Solids.

(*a*) Find the weight of half a dozen iron nails. Fill your density bottle with water. Replace the stopper, taking care that no air bubbles are enclosed. See that the outside of the bottle is perfectly dry. Place the iron nails and the density bottle full of water on the balance pan, and find their united weight. Remove the bottle from the balance pan and put the nails in it. Dry the outside of the bottle and again find its weight. The total weight is now less than when the nails were on the pan, outside the bottle. Decide for yourself to what this loss of weight is due. Express your results thus:

Weight of nails taken = …… grams

Weight of nails and bottle full of water = …… grams
Weight when nails are in the bottle = …… grams
$\therefore$ weight of water expelled by nails = …… grams

$$\therefore \text{ relative density of iron} = \frac{\text{weight of nails}}{\text{wt. of equal vol. of water.}} = \ldots\ldots$$

Calculate the density of iron as you did that of spirit, in the last exercise, from the number you obtained for the density of water.

* (*b*) In a similar way find the relative density of lead, using a number of small lead shot.

25. Determination of Relative Densities by Displacement of Liquids.

(*a*) Place a "bridge" or stage over one of the balance pans, and thus support a beaker over the pan, without interfering with its swinging (Fig. 13). By means of thin cotton tie a glass stopper to the hook just beneath that

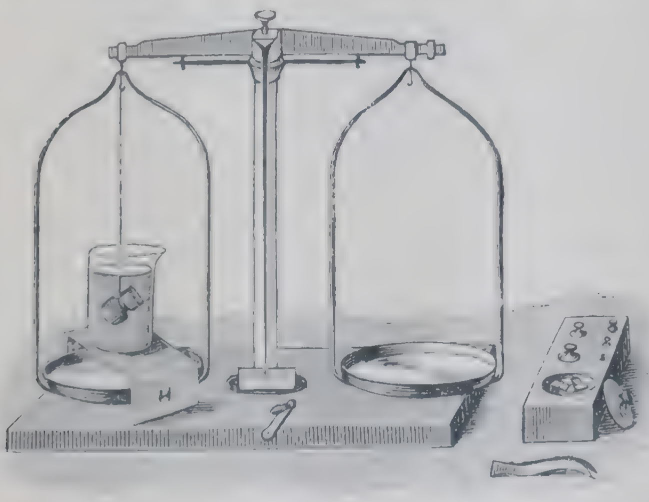

FIG. 13.—Balance with bridge for determining relative densities.

from which the pan is hung, so that the stopper hangs entirely within the beaker whether the balance beam is resting on its supports or has been raised from them. Take care that the stopper does not touch the sides or bottom of the beaker.

Find the weight of the stopper while in this position, placing an equal length of cotton on the same pan as the weights in order to balance that by which the stopper is suspended.

Pour into the beaker sufficient water to cover the stopper when it is swinging. Find the weight of the stopper as it hangs in the water. What change do you notice in its weight? Record your results in the following manner:

Weight of stopper in air = ... grams
Weight of stopper in water = ... grams

∴ (gain or loss) of weight = ... grams

Remove the stopper with the cotton still attached, and find its volume by lowering it into a measuring cylinder containing water. Calculate the *weight* of the volume of water displaced by the stopper. How does this compare with the change of weight found to be caused by hanging the stopper in water?

* (*b*) The previous experiment can be carried out in a more instructive manner if a balance with a pan specially arranged for density experiments can be obtained (Fig. 14). Hang the stopper from the hook below the left hand pan. Place in the pan itself a small graduated cylinder. In the opposite pan place weights sufficient to balance stopper and cylinder. Pour into a large graduated cylinder water sufficient to cover the stopper if the latter were allowed to hang in it. Notice the exact height at which the water stands in the cylinder. Place the cylinder below the left hand pan so that the stopper hangs in the

water without touching the sides of the cylinder. Observe the volume of water displaced by the stopper. Allow water to run gradually into the cylinder in the pan above from a pipette until equilibrium is just restored. Notice what volume of water is needed to restore equilibrium. Compare this with the volume displaced by the stopper. What conclusion must you come to?

* (*c*) Measure the lengths of several edges of a metal cube. If possible save time by obtaining the cube measured in Exercise 20 (*a*). Calculate the volume of the cube from the average length of one edge. Find what the water equal in volume to the cube would weigh. Find the loss in weight of the cube when weighed in water in a similar manner to that described in either of the previous sections. Compare this loss in weight with the weight of water displaced by the cube. What connection do you find?

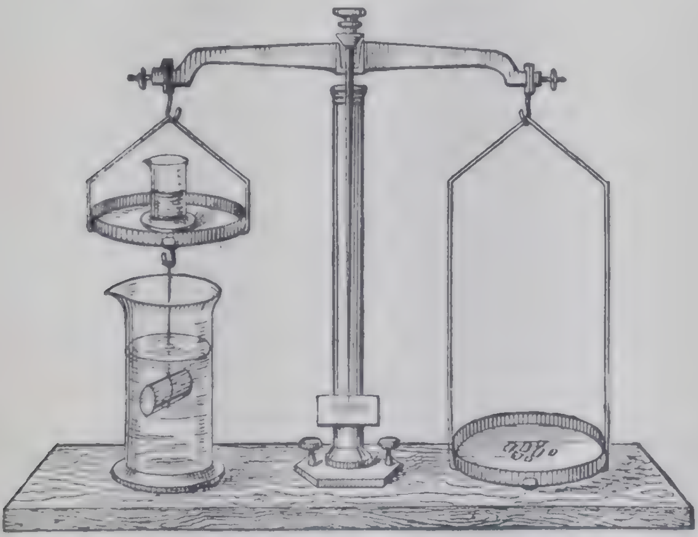

FIG. 14.—Hydrostatic balance for use in Exercise 25 (*b*).

* (*d*) From your knowledge of the volume of the cube used in Exercise (*c*), calculate the weight of spirit which would be displaced by it. Find the loss in weight of the cube when

weighed in spirit. Compare the weight lost with the weight of spirit equal in volume to the cube.

* (*e*) Find the weight which the cube used in Exercises (*c*) and (*d*) loses when weighed in paraffin instead of water. Assuming that the loss in weight is equal to the weight of paraffin displaced by the cube, write down the weights of paraffin and water respectively displaced by the cube. From these numbers calculate the relative density of paraffin. Write down these results as follows:

Weight of paraffin displaced by cube = …… grams
Weight of water displaced by same cube = …… grams
∴ relative density of paraffin

$$= \frac{\text{wt. of paraffin}}{\text{wt. of equal vol. of water}} = \ldots\ldots$$

From the value you have obtained for the density of water, calculate the density of paraffin.

ADDITIONAL EXERCISES. IV.

1. Find the relative density of vinegar by means of the density bottle.

2. Find the density of common salt by weighing a density bottle full of paraffin, and then finding the weight of paraffin displaced from the bottle by a weighed quantity of salt.

3. Weigh a glass stopper in air, water, and muriatic acid. From the numbers thus obtained calculate the relative density of the acid. Calculate also the weight of 1 c.c. of the acid.

4. Use the following method to find the density of naphthalene. Make a strong solution of salt in water. Place in the solution a piece of naphthalene. Thrust the solid below the surface. If the solution has been made strong enough the solid will return to the surface. Now

add water until the naphthalene will float in the liquid without rising to the surface. Make certain by stirring the liquid that it has the same density throughout. Finally, determine the density of the solution by any of the ordinary methods. Hence deduce the density of the solid.

5. Obtain a density tube. Examine and sketch it. Dry it carefully by warming it and blowing dry air through it. Find its weight. Attach a pipette to the wider end and draw distilled water into the tube through the narrower opening (Fig. 15, *A*). When the tube is full, and some liquid has been drawn into the funnel-shaped part (*B*), take off the pipette and draw the excess of liquid through the narrow tube by means of blotting paper, until the surface of the liquid in the capillary tube (*C*) is level with the mark there. Dry the outside of the tube. Find the weight of the tube and the water it contains. Hence calculate the weight of the water.

6. Empty and dry the density tube used in the previous exercise. Fill it with alcohol. Calculate the weight of alcohol held by the tube, and hence the relative density of alcohol.

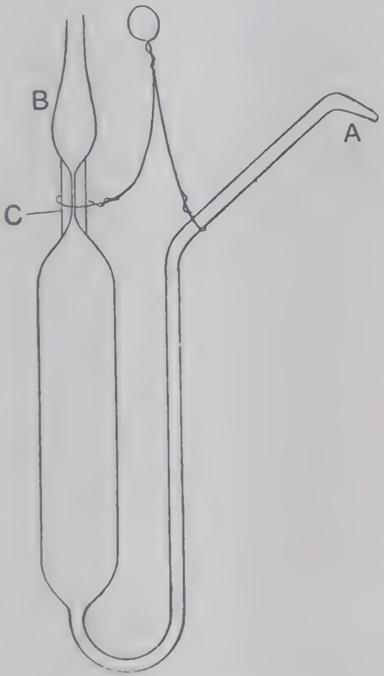

FIG. 15.—A density tube.

7. Fill a measuring flask with distilled water. Place it in a saucepan of warm water. Heat the saucepan until the water in it boils. Notice any change in the position of the water surface in the flask. When this has become steady adjust the water level to the mark by removing some of the water with a pipette. Take the flask from the saucepan,

allow it to cool and weigh it. Calculate the density of water near its boiling point (100° C.).

8. Surround the flask with broken ice. Adjust the water level to the mark. When this has been done, remove the flask from the ice. Wait until the temperature of the water is the same as that of the room and then weigh. Thus determine the density of water near its freezing point (0° C.).

9. Bend a glass tube about 1 cm. in diameter and 50 cm. long into the shape of a **U**. Pour into it sufficient mercury to fill the bend, and above the mercury into one arm pour water, into the other methylated spirit, in sufficient quantity to make the mercury surfaces level in the two arms. Measure the heights of water and spirit columns which balance one another. Calculate the relative density of spirit.

CHAPTER V.

COMMON MATERIALS. WATER.

26. Is Tap Water Pure?

(*a*) Heat a small quantity of water in a basin over a Bunsen flame. What happens to the water when it boils?

(*b*) Place a few drops of water on a watch glass. Instead of a watch glass a piece of broken flask will serve the purpose admirably. Heat the glass on an iron plate until the water has disappeared. Examine the glass carefully and see what is left on it. What appearance has this residue when examined by a pocket lens?

(*c*) Repeat the last experiment, using sea water in place of tap water. Taste the solid left behind. Describe its appearance under a lens.

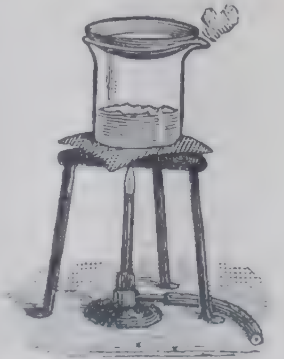

FIG. 16. Evaporation by means of steam.

(*d*) Ascertain the amount of solid dissolved in tap water in the following manner. Weigh a thoroughly dry porcelain basin. Measure into it 100 c.c. of tap water by means of a pipette. Boil away the water, at first gently over a bare flame, then, when only a third of the water is left, on a water bath over boiling water. If a water bath is not available the basin may be heated over boiling water contained in a beaker. Should the beaker be without a spout a chip of wood may be inserted between basin and beaker to allow of the escape of steam (Fig. 16). When most of the water has gone, add another 100 c.c. of tap water to what is left in the basin and continue the boiling.

When no water remains, dry the residue in a hot air oven. Allow the basin and contents to cool, and find their weight.

Enter these numbers in your notebook as follows:

Weight of basin and residue = ...grams
Weight of basin alone = ...grams
∴ weight of solid in 200 c.c. of tap water = ...grams

From this number calculate the weight of solid dissolved in 100 c.c. of tap water.

27. The Distillation of Water.

(*a*) Again heat some water in an open basin till it boils. Hold over the boiling water a piece of glass or porcelain. What do you find deposited on this cool surface? What suggestion can you make for a method of cooling and collecting the water as it passes into the air as steam?

(*b*) In order to prepare water free from dissolved solids, the water must be converted into steam and condensed again by cooling.

> This process of purifying water, by turning it into steam and then condensing it, is called **distillation** and the cooling apparatus is called a **condenser**.

Procure a Liebig's condenser and notice how a current of water can be passed through the outer jacket, while the steam passes through the inner tube. Procure a flask to hold at least a litre and corks which fit tightly into the mouth of the flask and into the inner tube of the condenser.

Connect the flask to the condenser by means of a glass tube of the shape shown in Fig. 17A. Place the flask on a piece of wire gauze over a Bunsen burner as shown in Fig. 17. Fill the flask two-thirds full of tap water and place in the water a few pieces of broken clay pipe. These make the water boil more easily and prevent "bumping." Place a smaller flask (Fig. 17, *C*) over the lower end of the inner tube of the condenser in which to collect the distilled water.

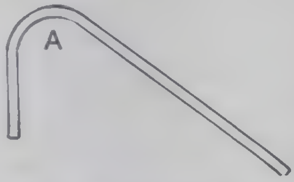

FIG. 17A.—Bent tube for use in Exercise 27(*b*).

This flask is called the **receiver**. The liquid collected is called the **distillate**.

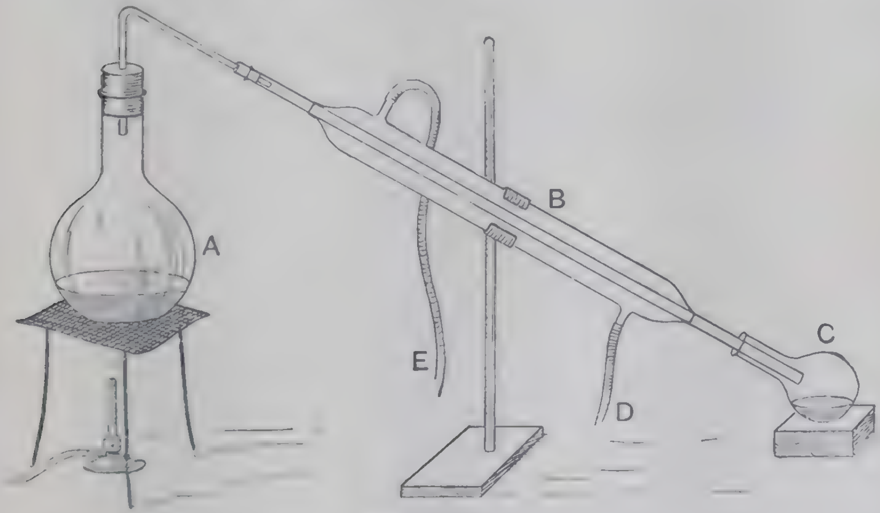

FIG. 17.—Apparatus for distillation.

Connect the *lower* of the two tubes (*D* in Fig. 17), which lead into the outer jacket of the condenser, to the water supply, and the upper tube (*E*) to the sink. Turn on the water so that a slow stream passes through the jacket.

Heat the water in the large flask and continue the process until most of the water has been distilled. Transfer the water as it is collected to your wash bottle.

(*c*) Heat some of the distilled water on a watch glass or piece of glass and ascertain if it is free from dissolved solid.

28. The Solubility of Solids and Liquids in Water.

(*a*) Place a few grains of sand in a test tube and shake with the sand a little *distilled* water. Heat the water. Does the sand seem to dissolve? Procure a small funnel and a filter paper which fits it. Fold the paper into halves (as in Fig. 18, i. and ii.) and again into halves (Fig. 18, iii.). Open out one of the four segments so that the paper forms a cone (Fig. 18, iv.). Fit this cone tightly into the funnel, and while holding it tightly in position, wet the paper with a few drops of distilled water (Fig. 18). Pour sand and water together into the filter and collect the liquid which passes through in a flask. Evaporate a few drops of this liquid on a piece of glass and find if any solid is left.

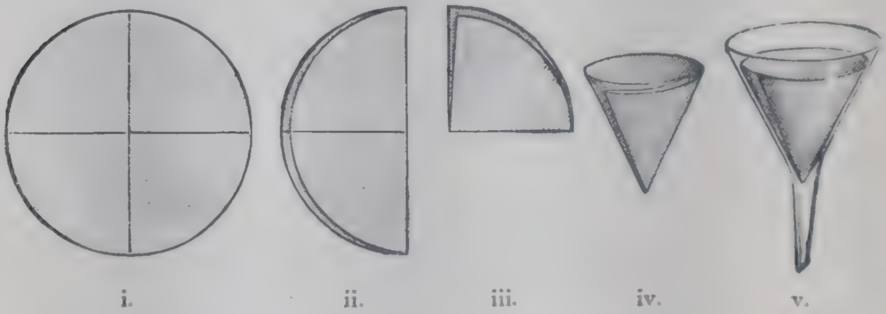

FIG. 18.—How to fold a filter paper.

Is sand soluble in water?

(*b*) Place a few drops of distilled water on a piece of glass and put into the water a grain or two of common salt. If this dissolves, add a little more. Continue to add salt, a few grains at a time, until some remains undissolved. Write down what you have learnt from the experiment.

(*c*) Ascertain the solvent power of water for Epsom salts and sugar, in a similar way to that used in the case of common salt.

*(*d*) Find how far clay, tea, and soap dissolve in water, using the method described in Exercise 28 (*a*). If nothing seems to dissolve, heat the water over a Bunsen flame. Filter the liquid if necessary, and boil a few drops to dryness on a piece of glass.

(*e*) Ascertain if the following liquids will dissolve in water: methylated spirit, paraffin, turpentine, ether, and benzene. In each case add a single drop of the liquid to one cubic centimetre of distilled water in a test tube. If the drop dissolves add more drops of the liquid. If it does not dissolve, add more water.

29. Separation of a Liquid and Solid from a Mixture of Them.

(*a*) Obtain the flask used for the distillation of tap water [Ex. 27 (*b*)] and measure into it 500 c.c. of distilled water. Dissolve in the water 25 grams of nitre. Fit together the distillation apparatus as used in Ex. 27 (*b*), and distil the water from the mixture, collecting the distillate as before. Meanwhile find the weight of a porcelain basin. Continue to boil the liquid until the solid begins to collect on the sides of the flask. Then stop the distillation and pour the liquid which remains into the porcelain basin, the weight of which you have found. Wash out the flask with distilled water and add it to the liquid in the basin, so that any solid from the sides of the flask is also transferred to the basin.

(*b*) Heat the liquid in the basin over a Fletcher burner until its volume is reduced to half, stirring it with a glass rod should it begin to spurt.

(*c*) Place the crystals and solution which are left behind in the basin on a water bath, and evaporate the solution to dryness over boiling water. Find the weight of the basin and its contents. Obtain by subtraction the weight of solid. Decide whether you have recovered the whole of it from the solution.

(*d*) Examine some of the crystals and compare them with nitre. Taste both. Do they differ in any way?

30. Separation of Two Solids from their Mixture.

(*a*) Write a description of the method by which you separated sand from water [see Ex. 28 (*a*)]. Is sand in any degree soluble in water?

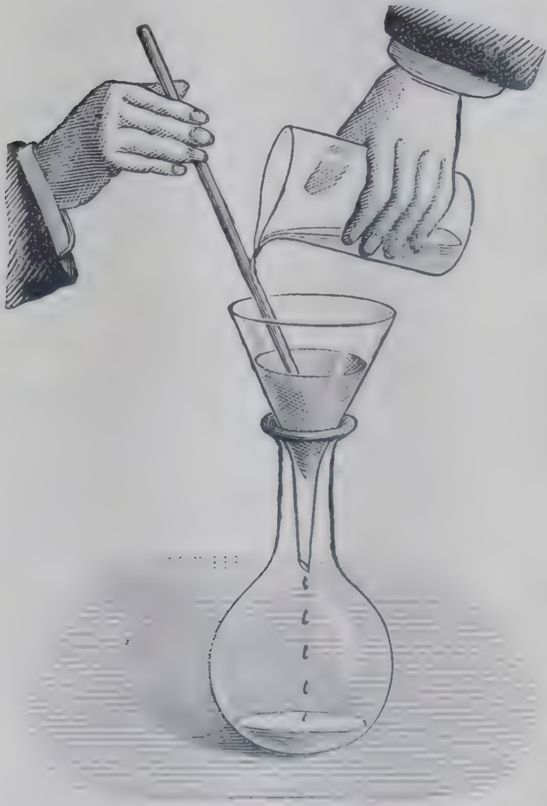

FIG. 13.—Decanting a liquid into a filter.

(*b*) Make a mixture of equal parts of sand and common salt. Decide how you can separate clean sand and clean salt from the mixture.

In order to effect this separation as quickly as possible, place the mixture in a flask and pour over it sufficient water to form a half inch layer over the solid. Shake the sand and salt thoroughly in the water and then allow the solids left to settle. Prepare a filter for use, in the way described in Ex. 28 (*a*). Obtain a glass rod. Raise the flask containing the mixture and pour the liquid steadily into the filter, holding the rod at the mouth of the flask so that the liquid runs down the rod (Fig. 19). Leave as much as possible of the undissolved solid in the flask. Pour a very little more water into the flask, wash the sand with it, and then pour it off as before into the filter. Collect the liquid which passes through the filter in an evaporating basin. Wash the sand once more with a fresh supply of water. Pour this also through the filter.

This method of separating a liquid from a solid by pouring off the liquid is called **decantation**.

(*c*) Evaporate the solution of salt to dryness, at first over a bare flame, then over boiling water in a water bath.

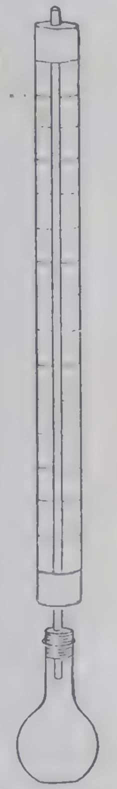

FIG. 20.—Flask and tube for use in Exercise 31(*b*).

31. The Results of Heating Water.

(*a*) Fill a flask with cold tap water half way up the neck. Heat the water over a Fletcher burner with a low flame until it boils. Notice carefully all that happens while the water is being heated and record your observations.

(*b*) Obtain a rubber stopper which fits the mouth of your flask tightly, and has one small hole. Through this hole pass a piece of glass tube at least half a metre long and with an internal diameter of not more than 3 mm.

Fill the flask with tap water so that when the cork is firmly in its place the water rises a short distance up the tube above the cork (Fig. 20). Prepare a paper scale divided into centimetres and half centimetres and fasten it to the tube. Heat the flask gradually, watching meanwhile the surface of the water in the tube. What changes in level do you notice?

When the water has risen to the top of the tube turn off the gas.

(*c*) Decide for yourself of what the bubbles noticed in the last two experiments may possibly be composed. In order to find out, make the following arrangements for collecting them. Make a delivery tube of the shape shown in Fig. 21. long enough to reach from the top of your large flask, when standing on the Fletcher burner, to the bench below. Cut a piece of glass tubing a few inches longer than seems necessary for the purpose. At one end make a gradual bend (Fig. 21, *b*); at the other make a sharper bend (Fig. 21, *c*), taking care that neither of the bends is twisted round. Cut the tube close to the gradual bend at *a*, and round off the sharp edges thus formed. Choose a one-holed rubber stopper which fits tightly into your flask. Arrange the whole apparatus as shown in Fig. 22.

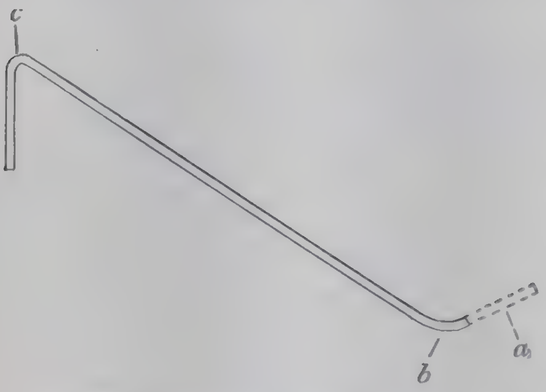

FIG. 21.—Tube bent for use in Exercise 31 (*c*).

Fill the flask to the brim with tap water. Fill the delivery tube also with water and then connect it with the flask. Fill a graduated cylinder with water. Close its mouth with your hand and invert it in a trough of water. Place the end of the delivery tube under the mouth of the cylinder. Heat the water in the flask and collect the bubbles as they pass over from the flask. When the water has boiled for some minutes and the volume of gas in the cylinder no longer increases, turn off the gas and remove the end of the delivery tube from below the cylinder, keeping the end below the surface of the water. Observe what happens as the flask cools. How do you account for the rushing back of the water to fill the flask?

When the gas collected in the cylinder has become cool raise the level of the water in the trough until it stands at the same height outside the cylinder as within. Determine the volume of gas which has been collected. Measure the volume of water which the flask and delivery tube contained at the beginning of the experiment. Calculate the volume of this gas dissolved in 100 c.c. of tap water.

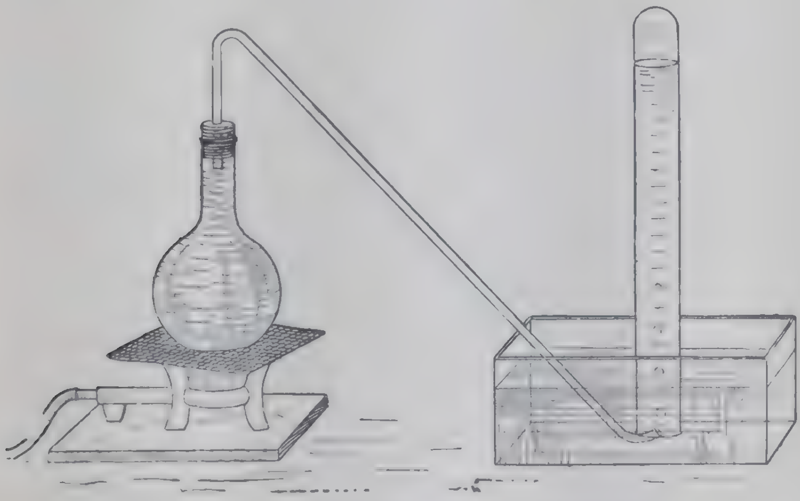

FIG. 22.—Collecting the gas from boiling water.

(*d*) Apply what simple tests you can to discover whether the gas you have collected is ordinary air. Close the mouth of the cylinder with a glass plate. Invert the cylinder. Smell the gas. Does it smell like ordinary air? Hold a lighted taper in it. Does the taper burn as it would in air? If necessary, collect a further quantity of the gas from a fresh supply of water.

*(*e*) Prepare water free from air in the following manner. Procure a flask which will hold at least a litre, and a cork to fit tightly into its mouth. Arrange a tube bent twice at right angles as shown in Fig. 23. Fill the flask with tap

water. Press the cork tightly into the mouth of the flask. Half fill a smaller flask with tap water and place the end of the delivery tube below the surface of this water so that it reaches to the bottom of the flask. Arrange the apparatus as shown in Fig. 23, so that both flasks can be heated by Fletcher burners.

Heat the water in both flasks. When the water has boiled for a few minutes turn out both flames. Observe carefully what takes place as the water cools, and write an explanation of what you see. The water in the larger flask is now free from air. What purpose does the water in the smaller flask serve?

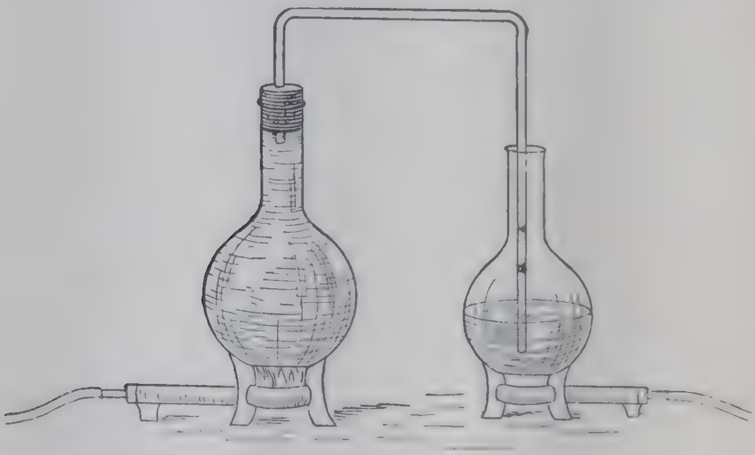

FIG. 23.—Preparation of water free from air.

ADDITIONAL EXERCISES. V.

1. Ascertain if the following solids will dissolve in distilled water: gypsum, soil, powdered coal, coffee. Filter the liquid only when necessary.

2. Find if the following liquids dissolve in water and whether they are easily soluble or not: vinegar, salad oil, "petrol," glycerin.

3. Compare the amounts of solid dissolved in rain water, spring water and river water. In each case filter the water to remove solids suspended in it.

4. Ascertain the solvent power of paraffin for (*a*) common salt, (*b*) sugar, (*c*) camphor, (*d*) turpentine, (*e*) spirit.

5. Find if methylated spirit will dissolve (*a*) salt, (*b*) shellac, (*c*) camphor, (*d*) soap, (*e*) turpentine, (*f*) sweet oil.

CHAPTER VI.

THE IDENTIFICATION OF LIQUIDS AND SOLIDS.

32. The Thermometer.

(*a*) Refer to your notes on Exercise 31 (*b*) and write down what happened to the water in the tube as it became hotter.

(*b*) Procure a flask and tube similar to those used in Exercise 31 (*b*). Fill the flask with methylated spirit so that the liquid rises in the tube above the cork. Place the flask in a vessel containing water and heat the water gradually. Observe the effect this heating has on the level of the spirit in the narrow tube.

(*c*) Obtain a mercury thermometer (Fig. 24). Sketch it. Write down the differences to be noticed between the thermometer and the apparatus in which you heated water and spirit in order to observe their expansion.

(*d*) Examine the scale of the thermometer. Write down the highest and lowest numbers marked on it.

> The numbers marked on the tube denote the lengths into which it is divided. They are called **degrees.** The same abbreviation is used to denote degrees on a thermometer as for the degrees in an angle.

Express your results thus: The thermometer is graduated from ...° to ...°. Each division represents

(*e*) Place the thermometer in a jar of cold water and note the temperature it records. Hold the bulb of the thermometer in your hand. What is the highest temperature reached? Place the bulb in your mouth beneath your tongue. Get someone else to take a reading of the temperature then recorded.

33. The Freezing Point of Water.

(*a*) Obtain a small quantity of ice and break it into small pieces with a sharp-pointed instrument, such as a bradawl. Fill a funnel with the broken ice. Bury in the ice the bulb of your thermometer. When the thread of mercury has become stationary, note the reading of the thermometer.

> The thermometers used in chemical experiments are always graduated according to the Centigrade scale, in which the melting point of pure ice is called 0° C. In Fahrenheit's system this degree is called 32° F. Fahrenheit marked as 0° F. the lowest temperature he was able to obtain.

(*b*) Mix the ice used in the preceding exercise with a quantity of salt in a small jar or beaker. Cover the bulb of the thermometer with the mixture. Note the reading and record all that you have observed. You have now used what is called a **freezing mixture**.

(*c*) Fit a narrow test tube with a cork. Bore a hole through the cork and fit the thermometer into it so that the bulb reaches almost to the bottom of the test

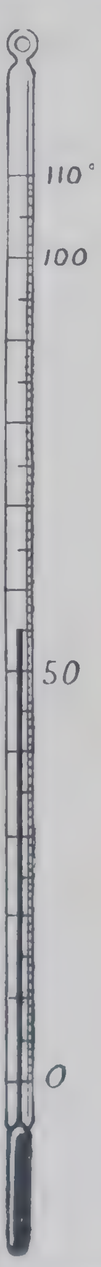

Fig. 24. A thermometer with Centigrade graduation.

tube (Fig. 25). Pour into the test tube distilled water sufficient to cover the bulb of the thermometer. Place the test tube in a freezing mixture of ice and salt and thus freeze the distilled water. Notice the reading of the thermometer from time to time.

When all the water is frozen, warm the bottom of the test tube in your hand until the cylinder of ice becomes detached and can be lifted up by means of the thermometer. Notice the temperature whilst the ice is melting in the air.

This method should always be used for determining the freezing point of small quantities of a liquid. By using a narrow tube an accurate determination can be made with less than 1 c.c. of water.

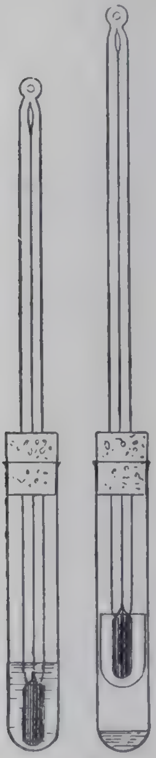

FIG. 25.—Determining the freezing point of water.

34. The Boiling Point of Water.

(*a*) Cut four grooves the whole length of the cork of your freezing-point apparatus, removing the thermometer before doing so (Fig. 26). Replace the thermometer in such a position that the bulb is half way up the test tube when the cork is in its place (Fig. 27). Wrap a very small wisp of cotton wool round the bulb. Place a few c.c of distilled water in the test tube. Add a fragment of broken clay pipe to facilitate regular boiling. Heat over a very small flame until the water boils and steam escapes from the grooves in the cork. Note the exact reading of the thermometer.

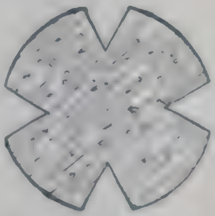

Fig. 26.—Cork with grooves for use in Exercise 34(*a*).

In the Centigrade scale the temperature at which water boils is marked 100° C. Fahrenheit called the temperature of the healthy human body 100°, and thus obtained the number 212° as the boiling point of water. The thermometer reads 100° C. and 212° F. only if

(i) the barometer column is 760 mm. high,

(ii) the mercury thread is completely immersed in the steam.

(*b*) Carefully push the thermometer down into the liquid and thus find the temperature of boiling water.

* (*c*) Repeat Exercises 34 (*a*) and (*b*), using tap water. What differences do you observe?

(*d*) Pour a few c.c. of distilled water into your test tube and add a small quantity of common salt. If all the salt dissolves add a little more until some salt remains undissolved at the bottom of the test tube. Find the temperature of the steam and of the boiling liquid.

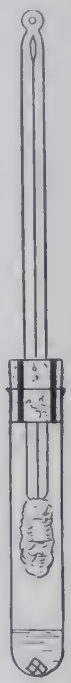

FIG. 27.—Determining the boiling point of water.

(*e*) Tabulate your results as follows:

	TEMPERATURE OF LIQUID.	TEMPERATURE OF STEAM.
Distilled water		
Tap water		
Salt solution		

(*f*) What conclusion do you draw from the results collected above? Can you now explain the fact that the temperature of boiling distilled water differs from that of boiling tap water?

(*g*) Decide how you could distinguish between pure water and water containing a dissolved solid.

* 35. The Determination of Coefficients of Expansion.

(*a*) In order to ascertain to what extent water expands as its temperature is raised, procure the apparatus used in

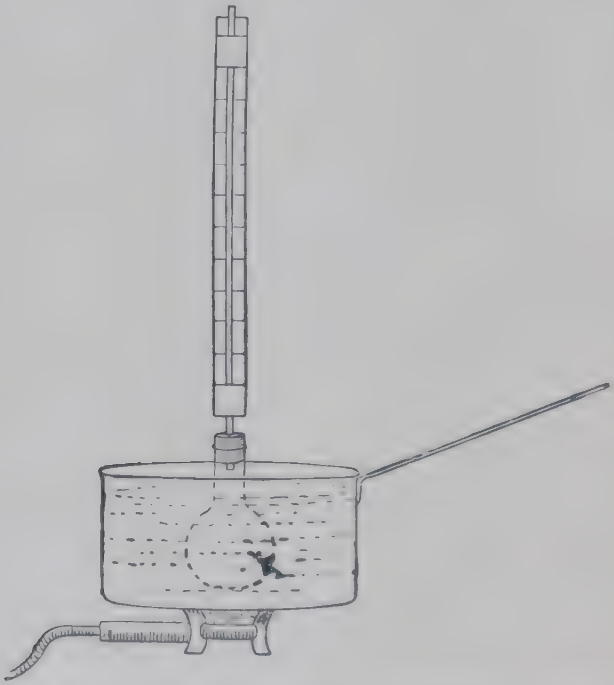

FIG. 28.—Determining the coefficient of expansion of water.

Exercise 31 (*b*). Remove the narrow tube from the flask, fill it with water and find the volume of the water. Measure the length of the tube and calculate what volume is held by 1 cm. length of the tube. Next fill the flask with distilled water and measure its volume. Replace the stopper and tube, taking care to exclude air bubbles. The water must reach to one of the lower divisions of the scale when the stopper is firmly in its place (Fig. 28).

Obtain a saucepan containing sufficient water to cover most of the neck of the flask. Place the flask in the water together with a thermometer. After the thermometer has been there a few minutes, note the temperature recorded by it and also the exact height of the water in the narrow tube. Place a burner beneath the saucepan and warm the water through about 10° C. of temperature. Stir the water with a stick and keep it steadily at this temperature for at least three minutes. Take an exact reading of the temperature recorded by the thermometer and of the height of water in the tube. Raise the temperature of the water gradually and repeat similar readings about every 10° C. up to 80° C. Record the results in the following manner:

TEMPERATURE.	HEIGHT OF COLUMN.	VOLUME BY WHICH WATER HAS INCREASED.	TOTAL VOLUME OF WATER.
15·6° C.	3·0 cm.	...	333 c.c.
25·2° C.	5·2 cm.	1·1 c.c.	334·1 c.c.
36·4° C.	7·6 cm.	1·2 c.c.	335·3 c.c.
45·0° C.	9·6 cm.	1·0 c.c.	336·3 c.c.
...	...	...	...

(*b*) Calculate the amount 1 c.c. of water expands when heated through 1° C., from the total expansion of the whole volume of water used in Exercise 35 (*a*).

... c.c. of water warmed through ...° C. expands ...... c.c.

∴ 1 c.c. of water warmed through 10° C. expands ...... c.c.

∴ 1 c.c. of water warmed through 1° C. expands ...... c.c.

The number thus obtained is called the **coefficient of expansion** of water.

(*c*) Express the results obtained in the last exercise by drawing a curve on squared paper. Mark along the hori zontal line a number of equal divisions each representing 10° C. and along the perpendicular line divisions of about the same size, each representing a volume about equal to that by which the water increased for every 10° C. (Fig. 29). Find the perpendicular line which represents the temperature in degrees, and mark on it a small cross at the point on it opposite the number which represents the volume of the water at the beginning of the experiment. Mark a second small cross at the junction of the two lines which represent the first of the higher temperatures to which the water was heated and the volume of water at this temperature. Repeat this for each temperature and the corresponding volume. Then draw a line without sudden bends which most nearly passes through all the crosses. Whether straight or curved it is called a curve. If one of the crosses lies far off the curve it must be neglected.

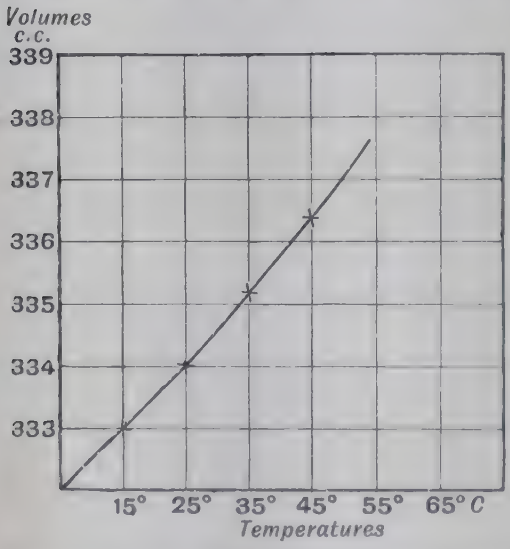

Fig. 29.—Curve showing the expansion of water.

The curve shown in Fig. 29 is drawn from the imaginary numbers given in Exercise 35 (*a*) for the expansion of water.

(*d*) Find the coefficient of expansion of methylated spirit between 15° C. and 55° C. in a similar manner to that used for water. Express your results by drawing a curve on the same piece of squared paper used in Exercise 35 (*c*). Compare the shape of the two curves. Write down what you think the differences in shape between them express.

36. The Determination of Melting Points.

(*a*) Place a few shavings of paraffin wax in a porcelain crucible. Warm the crucible gently with a Bunsen flame. Note the behaviour of the wax.

(*b*) In a similar manner discover what happens to lead when heated in a crucible. Does copper behave in the same way as lead?

(*c*) Heat a piece of fine copper wire (No. 36) in a blow-pipe flame. What takes place? Can iron be melted in the same way?

(*d*) Heat the middle of a test tube in the blow-pipe flame, turning it round quickly until the glass becomes quite soft all round. Draw out the soft glass at first slowly, then more quickly, to the full stretch of your arms. Cut the very fine tubing thus formed into pieces about 10 cm. long. Melt a little paraffin wax in a basin and dip the end of the tiny tube into it. Allow the wax thus introduced to set in the tube. Procure a small beaker. Support it on the ring of a retort stand over a piece of wire gauze, so that it can be heated from below (Fig. 30). Half fill the beaker with water. Place the bulb of your thermometer in this water and secure it in that position by means of a clamp fixed on the upper part of the retort stand. Fix the tube containing the paraffin wax to the stem of the thermometer so that it dips into the water. If it is moistened with the water, it will probably stick to the thermometer. If not, secure it by means of a very thin rubber ring cut from a piece of rubber tubing. Prepare a curved stirrer of glass rod, with which to keep the water constantly in motion.

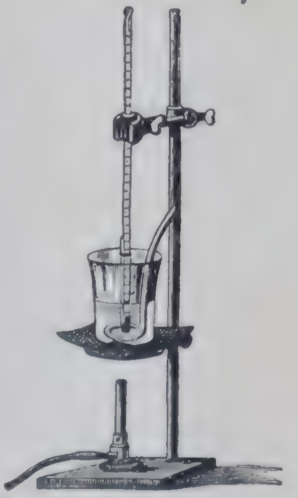

FIG. 30.—The determination of a melting point.

Heat the water *slowly* with a small flame, stirring it so as to keep it all at about the same temperature. Watch the wax carefully. When you see it beginning to melt, at once note the temperature recorded by the thermometer. Take the flame away. If the whole of the wax has not already melted, notice the temperature at which the last of it becomes liquid. State the result thus:

Melting point of paraffin wax = ... ° C.

* (*e*) Find the melting point of mutton fat.

* (*f*) Melt some mutton fat in a crucible and add to it a little paraffin wax. Find the melting point of the mixture. Compare it with those of the purer substances.

* (*g*) Use the same apparatus to find the melting point of sulphur. In this case, since water boils at a lower temperature than the melting point of sulphur, place glycerin in the beaker instead of water.

37. The Determination of Boiling Points.

(*a*) Procure some vinegar and find its boiling point, using the same apparatus as in Exercise 34 (*a*) for the purpose.

* (*b*) Determine the boiling point of methylated spirit, using the apparatus described in Exercise 34 (*a*), but placing the test tube in a beaker of water heated below with a Bunsen flame.

(*c*) Determine the boiling point of methylated spirit by means of the arrangement described below.

Close one end of a glass tube and bend it to the shape shown in Fig. 31 A. Pour some mercury into the tube and tilt it so that the air escapes and mercury fills the closed arm. The mercury level must be lower in the open than in the closed arm. Pour a few drops of spirit into the open arm, and again tilt the tube so that some of the spirit passes into the closed limb (Fig. 31, B).

Support the bent tube in a beaker of water (Fig. 31, C).

Heat the water gradually, keeping it well stirred. Place a thermometer in the water and read the temperature. At the same time watch the bent tube and, when the mercury becomes level on both sides of the bend, note the exact temperature to which the spirit has been heated. Explain as far as you can your reason for taking this temperature as the boiling point of spirit.

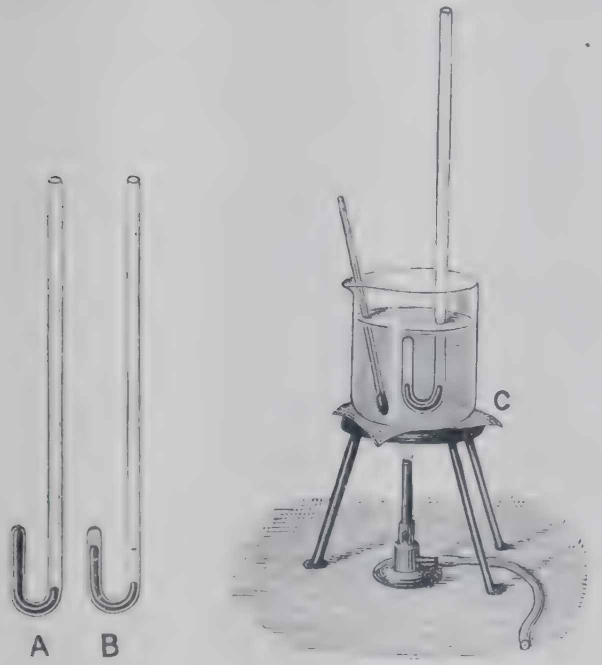

Fig. 31.—Determining the boiling point of methylated spirit.

* (*d*) Find the boiling point of water mixed with a quarter of its volume of methylated spirit. Does the temperature alter as the boiling is continued?

* (*e*) Determine the boiling point of water mixed with three times its volume of glycerin, using for this purpose a thermometer graduated to at least 300° C. At what point does the temperature remain constant?

* (*f*) Decide how you would recognize a mixture containing liquids of different boiling points.

ADDITIONAL EXERCISES. VI.

1. Determine the melting point of bees'-wax and of naphthalene.

2. Obtain a test tube and a cork which fits it tightly. Through a hole in the cork pass a glass tube bent at an obtuse angle (Fig. 35). In the test tube place some powdered washing soda. Over the free end of the bent tube slide a long and narrow test tube. Let this second tube dip into water in a bowl, so that as much of it as possible is kept cool. Heat the soda with a very small flame. Move the flame about constantly so that the tube may be heated as evenly as possible. Continue to heat the soda until you have collected about three c.c. of the liquid which is formed. Determine the boiling and freezing points of this liquid. Discover anything else you can about its properties. Finally decide what the liquid is.

3. Procure a beaker as long and narrow as possible. Make a file scratch on its side about an inch from the top. Find the volume of water it holds up to this mark. In the same way mark the level reached by a quarter and by a half of this volume of water. Prepare a solution of common salt in distilled water containing 5 grams of salt to 100 c.c. of water. Fill the beaker up to the highest mark with this solution.

Boil the solution and determine its temperature. Continue to heat the liquid until its volume is reduced to exactly one half. Find what is now its boiling temperature. Again continue to boil, until the solution occupies one quarter of its original volume. Again find the boiling point. Since the weight of salt in the solution has remained unchanged through these changes of volume, the proportion of salt to water must have been doubled when half the solution was left. When only quarter the volume remained the proportion of salt was four times as great as at first. Collect the results into a table.

Weight of Salt in 100 c.c. of Solution.	Boiling Point Observed.	Number of Degrees above Boiling Point of Water.

What conclusion do you draw as to the effect an increase of dissolved solid has on the boiling point of a solution?

4. Determine the boiling point of sea water by the method described in Ex. 34 (*a*).

5. Find the coefficient of expansion of turpentine for 1° C. at about 40° C. to 50° C.

AI BAHADUR ARCOT NARRAINSAMI MU
HIGH SCHOOL
BANGALORE.
ESTABLISHED
SEPTEMBER 1873.

CHAPTER VII.

COMMON MATERIALS: SALTS.

38. Rock Salt.

(*a*) Examine the rock salt provided. Break it into small pieces with a hammer or pestle. Examine one of these pieces under a pocket lens. Does it differ in shape from one of the larger lumps? Draw a crystal. Discover whether salt is soluble in water and in paraffin.

(*b*) Place a little of the broken rock salt in a small test tube. Heat the test tube in the Bunsen flame and write down exactly what happens to the salt.

(*c*) Determine the density of rock salt by the method used in Ex. 24 (*a*), but, since salt is insoluble in paraffin, use paraffin as the liquid instead of water.

(*d*) Grind a little rock salt to a fine powder in a mortar. Weigh a gram of the powder into a test tube. Add distilled water from a burette in small quantities at a time until the salt has dissolved. Shake well each time before adding a further quantity of water. State your results as follows:

...... c.c. of water dissolve 1 gram of salt.
100 c.c. of water dissolve ...... grams of salt.

*(*e*) Repeat this experiment, but instead of adding the water to the salt, add the salt to the water. Weigh a watch glass half filled with powdered rock salt. Measure 10 c.c. of distilled water into a beaker. Add the salt to the water

cautiously, using the same precautions as in Exercise 38 (*d*) until no more will dissolve. Weigh the watch glass again. Express the result in a similar way to that used in the last exercise.

(*f*) Prepare a *saturated solution* of rock salt (*i.e.* one which will dissolve no more salt) by shaking 100 c.c. of distilled water with so much powdered salt that a quantity of fine powder remains undissolved after repeated shaking. Note the temperature of the solution and then filter it into a weighed density bottle. Determine the density of this saturated solution.

(*g*) Weigh a small beaker and watch glass. Pour about 20 c.c. of the saturated solution from the density bottle into the beaker, cover this with the watch glass, and again weigh. Then remove the watch glass and evaporate the solution on a water bath. If a water bath is not available for this purpose the beaker may be supported by means of three corks in a larger beaker or a tin, half filled with water (Fig. 32). Dry the residue after evaporation in a hot air oven, and again weigh. Calculate the weight of salt dissolved by 100 grams of water in the following manner:

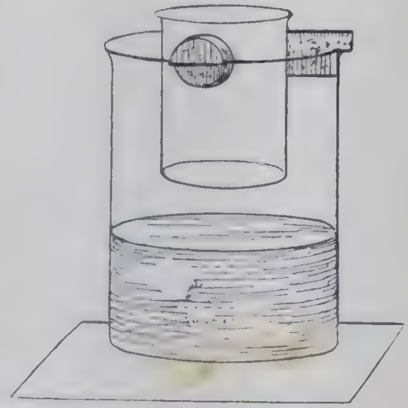

Fig. 32.—Arrangement for heating a beaker by steam.

Weight of beaker, watch glass and solution = ... grams
Weight of beaker and watch glass = ... grams
∴ weight of solution = ... grams

Weight of beaker, watch glass and residue = ... grams
Weight of beaker and watch glass = ... grams
∴ weight of salt in solution = ... grams

Weight of solution = ... grams
Weight of salt = ... grams
∴ weight of water = ... grams

∴ ...... grams of water dissolve ...... grams of salt.
∴ 100 grams of water dissolve ...... grams of salt.

Compare the result thus obtained with the values found in Exercises 38 (*d*) and (*e*). Which result do you consider most accurate? State your reasons.

39. The Purification of Salt.

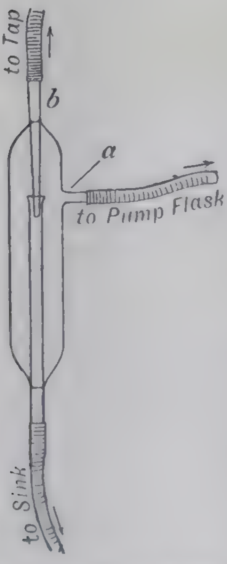

FIG. 33.—A filter pump.

(*a*) Dissolve 100 grams of rock salt in warm water and, in order to remove any insoluble part, filter the solution into an evaporating dish. Boil off the water carefully until a thick paste of crystals is left. If bumping occurs, stir the liquid with a glass rod. Separate the crystals from the liquid by means of a filter pump (see next Expt.) and keep both crystals and mother liquor [Ex. 39 (*c*)].

(*b*) Obtain a filter pump (Fig. 33). Examine it and make a careful drawing. Notice how the stream of water draws a current of air through the side tube (Figs. 33, *a*, and 34, *a*). Attach the thick walled tube from the side tube of the pump (Fig. 34, *a*) to the tube of a pump flask. Fit a funnel about 4 inches in diameter into the neck by means of a rubber stopper. In the funnel place a filter pump plate (Fig. 34, *c*) which is a thin porcelain plate perforated with many holes. Procure a filter paper a very little larger in diameter than the plate. Fit the paper on to the plate and place the latter into position in the funnel. Turn on the water which works the pump and pour a few drops of distilled water on the filter paper. See, that when the pump is drawing air through, the edges of the paper fit tightly against the sides of the funnel. See that the pump flask is dry. When the quantity of liquid is small, collect it in a test tube placed inside the pump flask (Fig. 34, *d*). The apparatus is now ready for use.

(*c*) Hold a glass rod against the lip of the basin containing the crystals, and pour them down the rod on to the filter. Hold the rod as shown in Fig. 19. When some of the water has drained through, press the crystals down firmly with a spatula and repeat this until they are dry. Keep the mother liquor (*i.e.* the liquid which has been drained from the crystals) for future use.

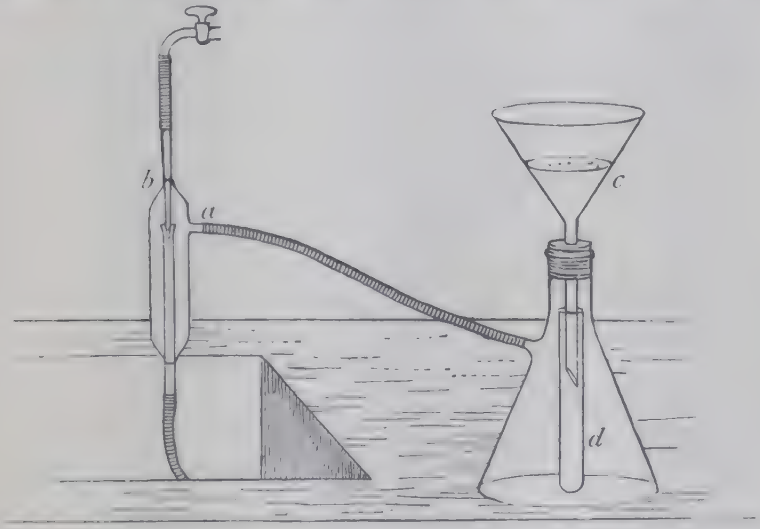

FIG. 34.—Filter pump attached to pump flask.

(*d*) Examine the crystals of purified salt with the unaided eye and under a lens. In order to examine them under the lens, place a few of them in a clean test tube. Damp the side of the tube with a drop of distilled water and shake the crystals on to the damp part so that they stick to it. This side of the tube can then be placed under the lens.

(*e*) To compare these crystals with the original rock salt more carefully, examine their physical properties, as far as time allows. Determine their solubility or the density of a saturated solution. Are the crystals soluble in paraffin? Determine the density of the crystals. Find what effect heat has on the crystals.

(*f*) Now examine the mother liquor from which the crystals were formed, since this may contain impurities more soluble than the purified salt. To see if this is so evaporate a measured volume of the liquid, and calculate the weight of solid dissolved in 100 grams of water. Compare this with the value obtained for the solubility of purified salt.

*40. Sea Water.

(*a*) Write an account of the chief differences between sea water and spring and river water so far as you know them.

(*b*) Determine the density of sea water.

(*c*) Taste the sea water. Evaporate a few drops on a watch glass and examine the residue under a lens.

(*d*) Evaporate a known weight of sea water to dryness, as in Ex. 38 (*g*). When the residue has been dried in an oven and weighed, replace it in the oven, dry it again, and again weigh it. If the weight has changed at all it was probably not quite dry during the first weighing. Repeat the drying and weighing until its weight no longer alters. Calculate the weight of solid matter in 100 grams of sea water.

(*e*) Keep the dried salt from the last experiment for a day or two, and then weigh it again. Has its weight altered at all? If so, try to find out the cause of this alteration.

(*f*) Boil down 2 litres of filtered sea water until a thick paste of crystals is left. Separate the crystals and mother liquor by means of a filter pump. Taste the crystals and mother liquor. Do you find any difference between them?

(*g*) Measure the density of the mother liquor. Compare it with that of a saturated solution of common salt [Ex. 38 (*f*)]. Do you think that sea water contains any substance more soluble than purified common salt? Keep the mother liquor.

(*h*) Recrystallize the crude sea salt you have prepared, as you did rock salt (Ex. 39). Notice, when doing this, if sea salt contains small quantities of any substance *less* soluble than the bulk of salt. Save the mother liquor from this experiment also.

(*i*) Compare the purified sea salt with the purified rock salt. Make as many measurements, as you have time for, of its physical properties—its solubility in water and in paraffin, the density of a saturated solution, and the density of the crystals themselves. Find also what effect heat has on the crystals.

41. Comparison of Rock Salt, Purified Salt and Purified Sea Salt.

(*a*) Draw up a table, comparing the properties of these three substances so far as you know them.

	ROCK SALT.	PURIFIED ROCK SALT.	PURIFIED SEA SALT.
Appearance of crystals			
Solubility in water			
Density of saturated solution			
Effect of heat			

(*b*) Compare carefully the properties here tabulated. Decide what are the differences and similarities between the three substances. Are they the same substance?

(*c*) Decide whether (i) rock salt, (ii) purified rock salt, (iii) sea salt, are single substances or mixtures of substances.

42. A Study of Alum Crystals.

(*a*) Examine some crystals of alum. Describe and draw them.

(*b*) Heat a few grains of alum at the bottom of a small test tube. State exactly what you observe.

(*c*) Ascertain, by one of the methods used for rock salt [Ex. 38 (*d*)], the solubility of alum in water.

(*d*) Weigh 25 grams of alum and dissolve it in a slight amount more water than the amount you would expect to be necessary from the result you obtained in the last exercise. Heat the solution in a basin until its bulk is reduced by one-third. Then set half the solution aside to cool. Continue to boil the other half. When spurting commences turn the flame quite low. Finally dry the contents of the basin in an oven.

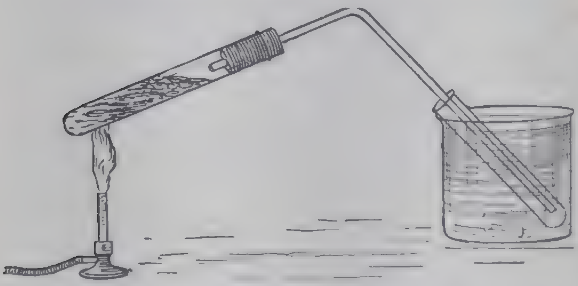

FIG. 35.—Collecting the liquid formed when alum is heated.

(*e*) Compare the two products formed in the last exercise. How do you account for the difference between them? Compare them both with the original alum. Which more closely resembles it? Write down any explanation you can give.

(*f*) In order to learn more about the composition of alum crystals, collect the liquid seen to be formed in Exercise 42 (*b*). Bend a piece of glass tube 20 cm. long at a rather obtuse angle (Fig. 35). Fit this tube into the mouth of a test tube by means of a tightly fitting rubber stopper. Place 10 grams of alum in the test tube. Fit the stopper into place. Over the end of the bent tube pass a test tube.

Arrange the apparatus so that this second test tube may be kept cool in water. Heat the alum, very gently at first, with a Bunsen flame, moving the flame about the whole time. Continue to heat more powerfully if necessary, until about half an inch of the collecting tube is full of the liquid that is formed.

(*g*) Take the boiling point of this liquid, in an ordinary test tube fitted with a cork and thermometer. In order to allow the steam to escape, cut two grooves in the sides of the cork. (See Exercise 26.)

(*h*) Leaving the thermometer still in the tube, place in it a mixture of ice and salt, and freeze the liquid.

(*i*) From these facts, and from the taste and smell of the liquid, decide what it is.

(*j*) With the additional information thus gained, decide what the difference must be between the crystals of alum and the white powder formed by heating them. To see if the crystals do differ by containing water, try if they can be reformed by adding water to the white powder formed by heating alum.

(*k*) From the knowledge you have obtained, decide whether a crystal of alum is a single substance or a combination of substances.

*43. The Influence of Temperature on Solubility.

(*a*) In order to discover if temperature has any effect on the amount of a solid which water can dissolve, arrange the following apparatus. Procure two boiling tubes and double-holed rubber stoppers which fit tightly into their mouths. Through each stopper pass two right-angled glass tubes, one reaching to the bottom of the boiling tube, the other just passing through the stopper. Over the lower end of one of the long tubes fasten tightly a piece of linen (Fig. 36, *a*) to act as a strainer. Arrange the apparatus as shown in Fig. 36.

Connect, by a rubber connection, the tube provided with the strainer to the short tube (Fig. 36, *b*) of the other boiling tube. Place both boiling tubes in a saucepan containing sufficient water almost to cover them. Connect the shorter of the two tubes which remain free (Fig. 36, *c*) to the filter pump, so that a current of air may be drawn through the apparatus. Place a thermometer in the water in the saucepan.

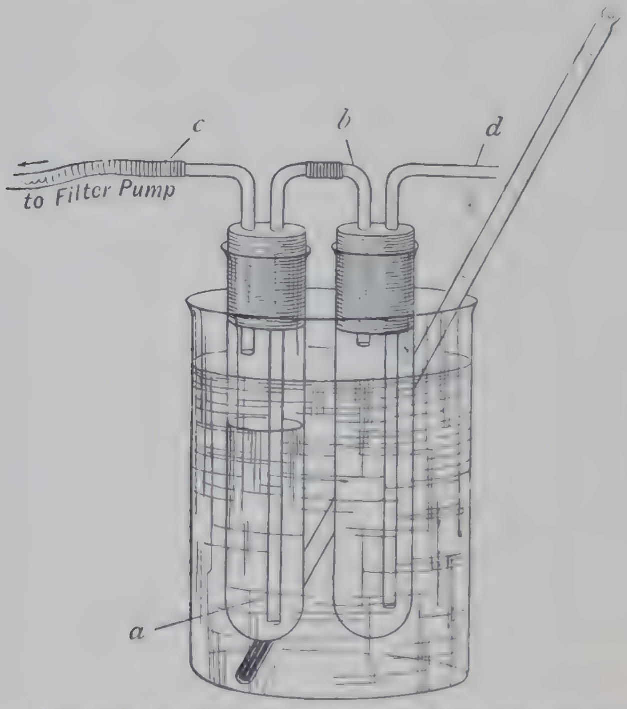

FIG. 36.—Apparatus for determining solubility at different temperatures.

(*b*) Remove the stopper from the boiling tube which contains the strainer and place in the tube about 50 grams of powdered washing soda. Fill the tube with distilled water to within two inches of the top. Replace the stopper and draw a slow current of air through the tubes by means of the filter pump. In this way the water above the salt is kept continuously stirred. After a quarter of an hour note the temperature recorded by the thermometer. By this time the water will have dissolved as much of the salt as is possible at the temperature.

Weigh an evaporating dish.

Remove the tube which connects with the pump. Disconnect the boiling tubes and connect them again so that *d* is now where *b* was. Attach the rubber tube from the pump to the free tube (Fig. 36, *b*), and draw half the solution through the strainer. Take the apparatus from the saucepan and pour the filtered solution into the weighed basin as quickly as possible. In doing this, take care that no water from the outside of the boiling tube drops into the basin.

Weigh the dish and its contents immediately.

Calculate what is the weight of solution taken. Boil off the water on the water bath. Complete the drying in the hot air oven. Weigh again and then find the weight of solid dissolved. State these results as in Exercise 38 (*g*), and calculate the weight of soda dissolved in 100 grams of water in the way there described.

(*c*) Repeat Exercise 43 (*b*) with the water in the saucepan kept at a temperature of about 25° C. Calculate the weight of soda dissolved in 100 grams of water at that temperature.

(*d*) Determine the solubility of soda at 35° C., 45° C., and 55° C., by the method described in Exercise 43 (*b*).

Collect the results thus obtained into a table. Include the measurement made at atmospheric temperature in Exercise 43 (*b*).

TEMPERATURE.	GRAMS OF SODA DISSOLVED BY 100 GRAMS OF WATER.
15° C. (about)	
25° C.	
35° C.	
45° C.	

(*e*) Express these results graphically by the use of squared paper, as you did your results in Exercise 35 (*c*). Mark degrees of temperature along the horizontal line and grams of salt per 100 grams of water along the vertical. Connect the points thus obtained by means of a regular curve, as shown in Fig. 29.

(*f*) In a similar manner find the effect of temperature on the solubility of common salt. Draw up a similar table and express the results you obtain in a curve. Is the effect of the temperature on the solubility of this solid as great as it is in the case of soda?

44. Other Common Salts.

(*a*) Procure some Epsom salts. Examine the crystals with the help of a lens. Sketch their shape.

(*b*) Heat some Epsom salts in a test tube and observe carefully what takes place.

(*c*) Determine the loss in weight of a gram of Epsom salts when heated. To what do you consider this loss in weight to be due?

(*d*) Determine the solubility of Epsom salts in water at the atmospheric temperature.

(*e*) Recrystallize 50 grams of Epsom salts (Ex. 39). Examine the substance thus obtained. Find what weight of it is soluble in 100 grams of water at the temperature of the room. Decide whether it differs from the original salt. Keep the mother liquor obtained from the recrystallization.

(*f*) Discover whether the mother liquor obtained in the preceding exercise contains substances more soluble than Epsom salts.

By aid of these results decide whether Epsom salts contains more than one substance besides its water of crystallization.

*(*g*) Try to obtain well formed crystals of Epsom salts in

the following manner. Prepare a saturated solution in distilled water. Decant 50 c.c. into a small beaker. Place the beaker over a flame and boil off a few c.c. of the liquid. Cover the beaker with a piece of paper and leave it for twenty-four hours. Examine it, and if no crystals have formed, evaporate it a little further. If many crystals have appeared, pour off the mother liquor into another beaker. Examine the crystals. Choose the one that seems to have the most regular shape, and place it in the solution again. Examine it again after the lapse of a day, and it will be found to have grown. Turn it over so as to expose fresh sides to the solution, and thus obtain a large-sized crystal.

(*h*) Study nitre (saltpetre) exactly as you have studied Epsom salts. Does it contain water of crystallization? Determine whether it is a single substance or a mixture. In what important respects do crystals of nitre differ from those of Epsom salts?

*(*i*) In a similar way discover the principal properties of crystals of baking soda (bicarbonate of soda).

ADDITIONAL EXERCISES VII.

1. Examine and describe (i) borax, (ii) washing soda, (iii) salammoniac, (iv) green vitriol. Find what their behaviour is when heated.

2. Determine the loss in weight of a gram of washing soda when heated.

3. Grow well-formed crystals of green vitriol.

4. Draw a curve showing the solubility of Glauber's salt in water at different temperatures. Do you discover any peculiar result of a rise of temperature on the solubility of the salt?

5. Carry out experiments in order to determine whether the following are single substances or mixtures of substances: baking powder, sea sand, black board chalk.

6. Study the effect of heat on blue vitriol. Decide what liquid it loses when heated, and what effect the loss of this liquid has on it. Prepare ordinary blue vitriol from the substance formed when it is heated. Would you class blue vitriol as a single substance or a mixture? Is it in this respect most like rock salt, common salt, or Epsom salts?

7. Are the following substances soluble in water: salts of sorrel, cream of tartar, water glass, chalk?

CHAPTER VIII.

COMMON MATERIALS: ROCKS AND EARTHS.

45. Sand and Flint.

(*a*) Obtain some sand. Examine it with the naked eye and under a lens. Can you see any clear outline to the crystals? Compare sand with quartz (quartz is the same substance in larger crystals). What is the distinction between the shapes of the two substances? Draw a quartz crystal. Can you scratch quartz with a knife?

(*b*) In order to obtain some cause for the difference between sand and quartz, write an account of the situations in which sand is most commonly found. Is it possible that the rolling of the sand on the sea shore may have something to do with the rounded nature of the crystals?

(*c*) Is sand soluble in water? If you are not certain what answer to give to this question, refer to your notes on Exercise 28 (*a*).

(*d*) From the knowledge you already possess, decide whether air has any action on sand, wet or dry. Does sand alter when left in the air?

(*e*) Place a few grains of sand in a test tube and find, by holding the tube for a moment or two in a Bunsen flame, what effect heat has upon them.

(*f*) In a similar way describe flint. Has it any crystalline shape? Determine the action of water and air upon it. What effect does heat produce on it?

(*g*) Try to pound a small piece of flint in a mortar. Can you crush it? Take another small fragment. Hold it for a few moments in the Bunsen flame by means of crucible tongs, and then drop it while hot into some water. Take it from the water and again pound it in the mortar. What difference do you now find?

46. Granite and Pumice.

(*a*) Examine and describe a piece of granite. Attempt to scratch the different parts of the rock with a knife blade. What do you find about their hardness? Does the rock seem to be a single substance or a mixture of substances?

(*b*) Break off a small piece of the rock. Determine if it is soluble in water by the method used in Exercise 28 (*a*).

(*c*) Examine the action of heat on another small piece.

(*d*) Obtain a piece of pumice. Examine it and write a description of what you see. Does it appear to be a single substance or a mixture?

(*e*) Grind some of the pumice in a mortar. Determine the solubility of pumice in water by treating some of the powdered pumice as you did the sand in Exercise 28 (*a*).

(*f*) Find, by holding a fragment in the Bunsen flame, what effect, if any, heat has on pumice.

47. Clay and Slate.

(*a*) Examine some clay. What appearance has it under the lens? Write down as many of its uses as you can.

(*b*) Find the effect of water on clay by the method used in Exercise 28 (*a*). Allow the clay to settle before you filter the liquid. Evaporate a few drops on a watch glass and thus find if the water has dissolved any part of the clay.

(*c*) Heat some clay in a test tube. Determine what effect heat has on clay.

(*d*) Does the clay appear to be a single substance or a mixture of substances? Give your reasons.

(*e*) Examine and describe slate. Find how hard it is by scratching it with a knife. For what purposes is it used?

(*f*) From the knowledge you already possess, decide whether it is likely that water dissolves slate. In order to test the truth of your statement, heat a piece of clean slate with distilled water in a test tube. Place a drop of this water on a watch glass and boil away the water. Do you find any solid left behind?

(*g*) Hold a piece of slate with your crucible tongs in the flame of a Bunsen burner. Has the flame any effect on the slate?

48. Limestone, Marble, and Chalk.

(*a*) Procure some limestone and examine it carefully. Powder a small fragment in an iron mortar. Examine the powdered limestone by means of the lens. Describe what you see. In the larger lump of the rock do you notice any part which appears different from the rest? If so, what appearance has it?

(*b*) Examine a piece of marble and compare it carefully with the limestone. What resemblances and differences do you notice? Scrape a little powder from the marble with a knife. Examine some of this powder under your lens. Describe and draw what you see.

(*c*) What are the uses of limestone? Do you know any substances which are prepared from it? Describe the method of manufacture if you can.

(*d*) Determine whether limestone is soluble in water, using the method described in Exercise 28 (*a*) in the case of sand.

(*e*) Hold a piece of limestone in a Bunsen flame by means of crucible tongs. Examine the limestone to see whether heat has had any apparent effect on it.

(*f*) Examine chalk in the same way as you have examined limestone. Write an equally full account of its appearance, as seen with the naked eye and with a lens, of the effect of water and of heat upon it, and of any use to which it is put.

49. Coal.

(*a*) Describe a piece of coal. Write what you know of its origin.

(*b*) Scratch it with a knife, and in this way obtain some idea how far it is harder or softer than the other substances you have dealt with in this chapter. Powder a fragment in a mortar. Notice in what directions it splits.

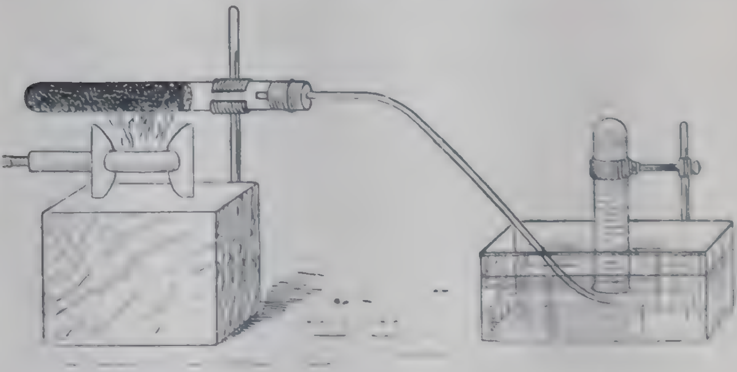

FIG. 37.—Collecting the gas from heated coal.

(*c*) Determine the solubility of the powdered coal in water by the method described in Exercise 47 (*b*).

(*d*) Wet some coal and leave it for at least a day in the air. After that time has elapsed, examine it and decide whether it seems to have changed in any way.

(*e*) Place a little powdered coal on an iron spoon, and hold it in a Bunsen flame. What takes place?

(*f*) Procure a piece of hard glass tube (about 2 cm. diameter) closed at one end, and place in it a layer, two inches deep, of powdered coal. Fix tightly in the mouth of the tube a rubber stopper fitted with a glass tube about 50 cm. long. Bend this long tube, so that when the hard glass tube is fixed in a horizontal position the longer tube reaches nearly to the bottom of a bowl of water (Fig. 37). When the apparatus is thus arranged, heat the tube, at first gently, then more fully, by means of a Fletcher burner. Do not allow any water which may collect to run on to the hot part of the tube. Collect the gas which is formed in a test tube full of water, inverted in the bowl over the mouth of the delivery tube. Allow the first tube of gas which is collected to escape into the air, smelling it as you do so. When you have a second tube full of the gas, raise it from the water, keeping it still mouth downwards. Bring a lighted taper to the open end and observe what takes place. What do you judge this gas to be?

(*g*) How do you consider that coal differs from the other minerals you have examined in this chapter?

50. Iron Ores.

(*a*) Procure some iron pyrites. If the lump has not already been broken, break it with a hammer or iron pestle. What appearance has the end of the broken lump? Try to scratch the end with your knife. Detach one or two of the crystals. Sketch the broken end.

(*b*) Discover whether the iron pyrites is soluble in water.

(*c*) Heat a small fragment of pyrites in a test tube. What effect is caused by heat?

(*d*) Examine the piece of haematite provided. Describe and draw its peculiar shape. Find how easily it can be scratched with a knife, and what is the appearance of the powder thus formed.

(*e*) Determine how far haematite is soluble in water. Find also what effect heat has on it by holding a piece of it in a Bunsen flame by means of crucible tongs.

(*f*) In a similar way describe some clay ironstone Scrape a little from the lump and examine the powder. Does it seem to be all the same substance?

(*g*) Find if the powdered ore is in any way soluble in water. Can it be separated into two parts by shaking it with water and pouring off the part that remains suspended?

(*h*) Discover if heat has any marked effect on the ironstone.

(*i*) Compare the three substances, pyrites, haematite and clay ironstone. Try to determine which are single substances and which mixtures.

51. Galena and Tinstone.

(*a*) Make a careful examination of the galena provided. Has it a crystalline shape? Describe its shape and sketch it. Can it be scratched easily with a knife? Examine any powder you can scrape from it—(i) with the naked eye and (ii) with the aid of a lens.

(*b*) Discover whether it is soluble in water and what effect heat has on it. Heat a small portion in the flame and another portion in a test tube. Mention everything you observe.

(*c*) In an exactly similar way examine and write an account of a piece of tinstone.

(*d*) Do you consider (i) galena, (ii) tinstone, to be single substances or mixtures of different substances?

ADDITIONAL EXERCISES VIII.

1. Procure some calcite and compare it carefully with limestone and with calc-spar.

2. Examine and describe gypsum. Determine if it is soluble in water, and find what effect heat has upon it. Heat it in a test tube with the Bunsen flame.

3. Procure some soil. Make a careful examination of it and try to separate it into as many constituents as possible. Place some in a flask and shake it with distilled water. Find if part has dissolved in the water. Endeavour to separate other constituents by shaking it again with water. Decant off the muddy water and thus obtain the denser part separately. Finally, decide how many constituents you can recognize.

4. Procure a piece of sandstone and, after a careful examination, decide what difference there is between sandstone and sand.

CHAPTER IX.

ACIDS AND THEIR PROPERTIES.

[NOTE.—**In handling the acids mentioned in this chapter be extremely careful to keep them from touching your skin or clothing, or serious damage may result.**]

52. Oil of Vitriol.

(*a*) Obtain some commercial oil of vitriol. Bear in mind the caution given above. Describe its more obvious properties.

(*b*) Dry a 100 c.c. measuring flask thoroughly and find its weight. Fill it to the mark with oil of vitriol. *See that the outside of the flask is free from acid.* Weigh the flask and liquid. Hence calculate the weight of 1 c.c. of the oil of vitriol. Keep the oil of vitriol for use in the following exercise.

(*c*) Measure into a flask 350 c.c. of distilled water.[1] (*Caution. See footnote.*) Pour gradually into the water 50 c.c. of the oil of vitriol which you weighed in the last exercise. Feel the bottom of the flask with your hand. Record in your notes what you observe. Shake the flask until the liquids are thoroughly mixed.

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[1] In diluting oil of vitriol with water always add the acid to the water. If the process is reversed, so much heat is formed round each drop of water that it may be converted into steam and the strong acid be splashed out of the vessel over hands or clothing.

(*d*) Pour about 10 c.c. of the solution you have just made into a small evaporating dish. Heat it over a small flame in the draught cupboard, turning down the flame still lower as the liquid disappears. Note all that takes place.

(*e*) Pour four drops of the diluted oil of vitriol into a test tube full of water. Shake the mixture thoroughly and taste a drop of it.

(*f*) To the very dilute acid you have just made, add a few drops of a solution of the dye "litmus." Compare the colour formed with that of the original litmus solution.

(*g*) Pour a little of the dilute acid prepared in Exercise 52 (*c*) on some powdered chalk in a test tube. Note what happens. Does the acid have the same effect on marble?

(*h*) Place two or three pieces of granulated zinc in a test tube. Pour over them an inch layer of dilute oil of vitriol. What happens to the zinc?

(*i*) Repeat the last exercise, using copper turnings in place of the zinc. Is the result the same?

(*j*) Place a pinch of iron filings in a test tube. Add a small quantity of the dilute acid. Describe what you see take place.

(*k*) Sharpen the plain end of a match. Dip it into strong oil of vitriol and write with the moistened match on a piece of paper. Warm the writing at some distance above a Bunsen flame. Describe the result.

(*l*) Place a few grains of common salt in a test tube. Pour on it a few drops of concentrated oil of vitriol. Warm the mixture gently. What is formed? What smell has it? Note what happens to the salt.

(*m*) Put a few small lumps of nitre or saltpetre in a test tube. Pour on them two or three drops of concentrated oil of vitriol. Warm the mixture cautiously and describe what takes place.

53. Acetic Acid.

(*a*) Obtain some vinegar. Smell it and taste it. What description would you give of the taste? Boil a little in a test tube and smell the fumes. Make a note of these more obvious properties.

(*b*) Pour a few drops of vinegar over some powdered chalk and note what takes place.

(*c*) Place a drop of vinegar on a piece of litmus paper (this is prepared by soaking paper in litmus solution). What effect is produced on the dye?

(*d*) Distil some vinegar in an apparatus similar to that described in Exercise 27 (*b*). Pass a thermometer through the cork so that it dips into the vinegar. Note the changes in temperature during the process. Collect about 50 c.c. of the distillate. Compare it with the vinegar remaining in the flask. What effect has the distillate on litmus and powdered chalk and marble?

(*e*) Now procure some acetic acid and study its appearance and smell. Warm a little in a test tube and cautiously smell the fumes.

(*f*) After diluting some acetic acid with 20 times its volume of water, taste it.

(*g*) To some more of the strong acid add three times its volume of water. Study the effect of this diluted acid on litmus solution and on chalk.

(*h*) From a comparison of these results with those obtained in Exercises 53 (*a*), (*b*), (*c*) and (*d*), decide what differences there are between vinegar, the liquid distilled from vinegar, and acetic acid.

(*i*) Pour a small quantity of diluted acetic acid over a piece of granulated zinc in a test tube. If no results are apparent, warm the mixture. Describe what takes place. Discover what effect the acid has on iron filings and copper turnings.

54. The Action of Oil of Vitriol on Common Salt.

(*a*) Obtain a flask holding about 500 c.c. and find a sound cork which is just too large for it. Wrap paper round the cork and roll it on the floor to soften it; continue this until it will fit into the mouth of the flask. Cut a piece of glass tubing 20 cm. long. Round off the ends. Bend it at right angles so that one arm is twice as long as the other (Fig. 38). Procure also a dropping funnel. Bore two holes in the cork into which the bent tube and dropping funnel fit tightly. Melt some fragments of paraffin wax in a small basin and soak the cork in it. Fit tube and funnel into the cork again and pour a little of the melted wax round the joints so as to lessen the risk of leakage. Prepare a second tube like the one you have already bent and connect its shorter arm to the end of the other tube by means of a short rubber tube. See that the ends of the glass touch beneath the rubber (Fig. 38). Place in the flask 20 grams of fused common salt or of rock salt, tilting the flask while pouring in the salt. Arrange the apparatus so that the flask can be heated and let the delivery tube pass nearly to the bottom of a thoroughly dried gas cylinder. Place between the flame and the bottom of the flask an asbestos mat or a piece of wire gauze.

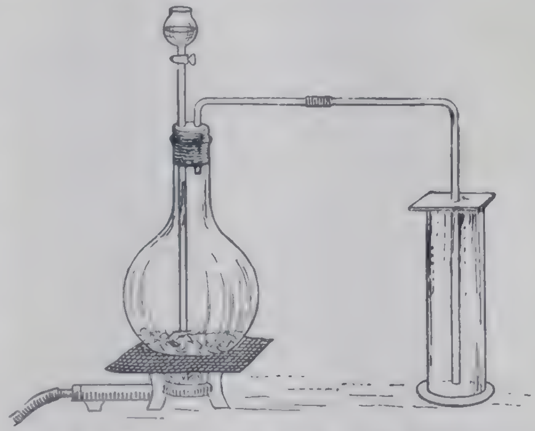
FIG. 38.—Collecting the gas from oil of vitriol and salt.

While arranging this apparatus, commence diluting 50 c.c. of oil of vitriol by adding it to half its volume of water. Pour half the diluted acid on to the salt by means of the dropping funnel and heat the mixture gently. Cover the top of the cylinder so far as possible with a ground glass plate or a piece of cardboard pierced with a hole for the delivery tube. When fumes begin to issue, thrust a lighted taper into the jar. Hold a piece of damp litmus paper within the jar. What proof have you that the jar contains some gas other than air? Write as full an account of it as you can.

(*b*) Measure into a test tube 2 c.c. of water. Remove the gas cylinder and quickly place the end of the delivery tube in the water in the test tube. Regulate the flame so that the bubbles enter the water slowly enough to be counted. Observe and note what takes place. So soon as entire bubbles begin to pass through again, remove the tube from the water and then turn out the gas. Place the whole apparatus in the fume cupboard. Continue to heat the flask until all the salt is dissolved. Keep the liquid in the flask for use in Exercise 54 (*h*). Write your explanation of all that you have seen.

(*c*) Warm a little of the liquid thus formed in the test tube and smell the fumes. Add to it a drop or two of litmus solution. What change is there in the litmus?

(*d*) Dilute four drops of the liquid with 15 or 20 times their volume of water. Taste the solution. To what class of substances would you say that the liquid belongs?

(*e*) Procure some muriatic acid, or spirits of salt, and compare it carefully with the liquid you have prepared from salt. Find the effect which muriatic acid has on litmus. Warm it in a tube and smell the gas formed. Dilute a few drops with a quantity of water and taste the very dilute acid thus formed.

(*f*) Dilute separately muriatic acid and the liquid you have prepared from salt with three times their volume of water. Try the effect of each of the diluted acids on powdered chalk, on granulated zinc, on copper turnings, and on iron filings.

(*g*) After studying the results obtained in the previous exercise, decide for yourself and write down how muriatic acid may be prepared.

(*h*) Pour the liquid left in the flask in Exercise 54 (*b*) into a basin half full of distilled water. Wash the flask out with distilled water and pour the washings also into the basin. Heat the basin until a portion of the liquid deposits crystals on being cooled. When this is the case, set the liquid aside to cool. As soon as a "crop" of crystals has formed, separate them and recrystallize them as you did the salt in Exercise 39 (*c*). Dry the crystals. Discover what weight of them can be dissolved in 100 grams of water. Determine the density of a saturated solution as directed in Exercise 38 (*f*). Heat a few of the crystals in a test tube. In all these ways note how the crystals differ from common salt.

> When, as in the preceding Exercise, substances act on one another, so as to form entirely different substances, a **chemical action** is said to take place. This must be carefully distinguished from a **physical change,** where no different substance is formed.

(*i*) State any cases of physical change which you have studied. What other example of chemical action have you noticed?

> The name **muriatic acid** was used for many years to indicate the strong acid solution generally called "hydrochloric acid." The name **hydrochloric acid gas** will be used in this book when the gas itself is meant.

55. The Action of Oil of Vitriol on Nitre or Saltpetre.

(*a*) Place in an eight ounce retort 25 grams of nitre or saltpetre. Pass a funnel through the mouth of the retort and pour over the nitre 25 grams of oil of vitriol, taking care that none of the acid runs down the long neck of the retort. Replace the stopper and fix the retort in a clamp so that it can be heated. Over the mouth place a small flask so arranged that it can be kept cool by a stream of water (Fig. 39). Heat the mixture on a sand-bath, gently at first, afterwards with a fuller flame. See that the small collecting flask is kept cool. Describe what takes place. When the contents of the retort begin to dry at the sides, turn out the flame. Remove the small flask with the liquid which you have collected in it. Pour the contents of the retort at once into an evaporating basin. Reserve them for use in a later exercise.

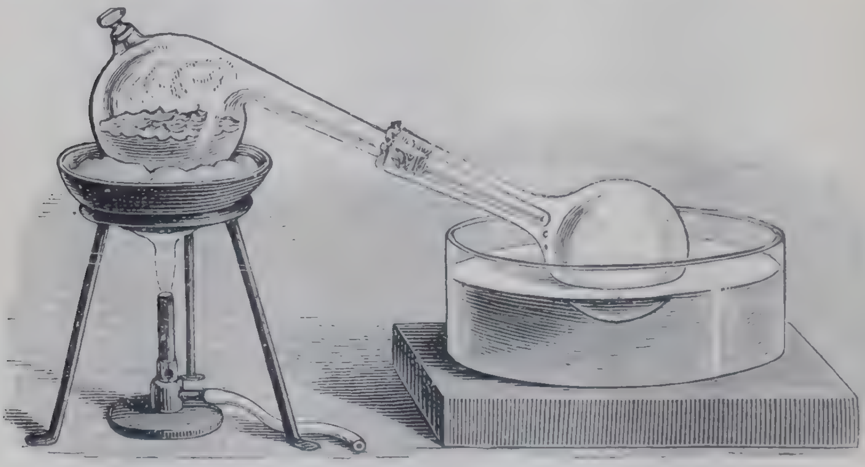

FIG. 39.—Collecting the liquid from nitre and oil of vitriol.

(*b*) Examine the liquid you have collected in the flask. Smell the fumes which rise from it. Heat a little in a test tube. What takes place?

(*c*) Dilute four drops of the liquid with 15 or 20 times their volume of water. Taste a drop of this dilute solution.

(*d*) Add a drop or two of the liquid to a little litmus solution mixed with water. What is the effect on the colour of the litmus? To what class of substances do you consider the liquid you have prepared belongs? Give your reasons for your answer to this question.

(*e*) Procure some commercial *aqua fortis* or nitric acid. Warm a little in a test tube and smell the fumes. Find the effect a drop of it has on litmus solution. Compare it with the liquid you prepared in Exercise 55 (*a*).

(*f*) Dilute separately small quantities of nitric acid and the liquid you have prepared with three times their volume of water. Find the effect, if any, of the diluted liquids on chalk, on granulated zinc, on copper turnings, and on iron filings.

(*g*) Make a careful comparison of nitric acid and the acid you have made from nitre. What are their resemblances and differences? Finally decide how nitric acid may be prepared.

(*h*) Find the density of strong nitric acid, using the same method and adopting the same precautions as you did in the case of strong oil of vitriol [Ex. 52 (*b*)].

(*i*) What effect has strong nitric acid on paper, on cloth, and on other similar materials?

(*j*) Examine the liquid poured from the retort in Exercise 55 (*a*). Separate the crystals which have formed in it by pouring off any liquid which is left into another vessel. Dissolve the crystals in as small a quantity of water as possible, and evaporate this solution until you again obtain the crystals from it. Examine them carefully, and perform any experiments you can in order to satisfy yourself that they are not composed of saltpetre. Is the change studied in Exercise 55 (*a*) a chemical or a physical one?

> The name **aqua fortis** was applied to this acid because it was so "powerful" a solvent of metals. Its other name, **nitric acid**, is due to the fact that it can be prepared from "nitre."

56. Comparison of the Foregoing Observations.

(*a*) From the results obtained, construct and fill in a table like the following:

	Taste.	Action on Litmus.	Action on Chalk and Marble.	Effect on Metals.		
				Zinc.	Copper.	Iron.
Oil of vitriol						
Muriatic acid						
Aqua fortis						
Acetic acid						

(*b*) Study the table you have thus made out, and with its aid write an account of the properties of acids as a class.

(*c*) In what respects have you discovered a difference between the properties of nitric acid and those of the other three?

ADDITIONAL EXERCISES IX.

1. Discover what effect, if any, strong muriatic acid has on paper, on salt, and on nitre.

2. Examine the solid substance tartaric acid and discover what acid properties it possesses. Dissolve it in water and compare the solution thus formed with the acids you have already examined.

3. Procure a lemon. Squeeze the juice from it and filter it through a fluted filter paper. Pour hot distilled water over the pulp which remains on the filter paper so as to wash through as much as possible of the juice. Discover what acid properties the juice has.

CHAPTER X

AIR AND ITS PROPERTIES

57. Air has Weight.

(*a*) Fit a 500 c.c. flask with a glass tube about 50 cm. long, by means of a rubber stopper bored with one hole through which the glass tube passes. Obtain a bowl, or trough, and fill it with water. Hold the flask upside down and press the mouth of the tube below the surface of the water as far as you can. Does the water rise inside the tube to the same level as it stands outside? Write down what you consider to be the reason for this.

(*b*) On to the end of the tube slip a short piece of rubber tubing 4 cm. long, and to this fix another glass tube also 4 cm. in length. Place a clip on the rubber tube (Fig. 40). Open the clip and suck out some air; let the clip close again while the tube is still in your mouth. Now place the end of the tube under the water in the basin and open the clip. Note what happens and try to explain it.

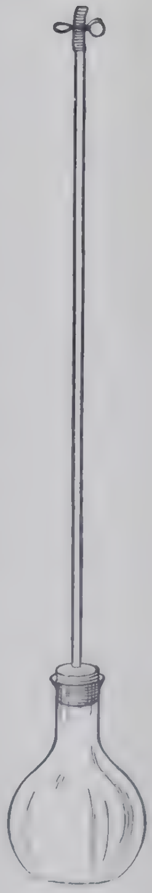

FIG. 40.—Flask arranged for use in Exercise 57 (*b*).

(*c*) Replace the long glass tube by another about 10 cm. long. To this fix the tubing and clip, as before. Dry the apparatus carefully and weigh it. In weighing so large an object as this, take care that the balance pan swings freely. The flask should be tied to the pan support if it will not stand steadily. Remove some air and close the clip, as you did in the last exercise. Weigh the flask and its contents again. What has taken place? Open the clip for a moment and weigh again. From the weighings thus obtained, calculate in two different ways the weight of the air drawn out.

(*d*) What therefore does the flask contain when in the state generally called "empty"? Write down as full an account as you can of the appearance and properties of this substance.

(*e*) Repeat the weighing of the flask and then, with the clip open, warm it for a few minutes over a flame. Close the clip. Let the flask cool and weigh it again. What do you find has happened? How can you explain this?

58. The Density of Air.

(*a*) Obtain again the apparatus used in Exercise 57 (*c*) and weigh it carefully. Drive out some air by warming the flask and replace the clip. When flask and contents are cool, weigh them again. Note the weight of air driven out. Then open the flask with mouth under water and measure the volume of water that enters. See that the heights of the water inside and outside the tube are the same. State why you think this precaution necessary.

(*b*) Repeat this work several times, removing different volumes of air each time. Dry the flask carefully on each occasion. Tabulate your results in the following way:

VOLUME OF AIR REMOVED.	LOSS OF WEIGHT OF FLASK AND CONTENTS.	WEIGHT OF 1 C.C. OF AIR.	WEIGHT OF 1 LITRE OF AIR.

* *(c)* Obtain a round-bottomed flask holding about half a litre. Fit it with a tightly fitting rubber stopper through which passes a short glass tube. On the glass tube slip a short rubber tube provided with a *screw* clip. Pour about 100 c.c. of water into the flask. Replace the stopper and, opening the clip, boil the water. When steam has been issuing freely for some time, remove the flame and *at once* screw the clip tight.

When the flask is cool, does it contain anything besides the water at the bottom? Allow the flask to stand till it has reached the temperature of the room. Dry the flask and suspend it by means of cotton above one of the pans of your balance. Hang it from the second hook. If there is no second hook, tie the cotton to the pan support itself.

Find the weight of the flask. Open the clip and allow air to enter. Note the increase in weight of the flask. Measure the volume of water in the flask during the weighing and the total volume of water the flask holds up to the level to which the stopper was pushed. In this way, obtain the volume of air admitted into the flask when the clip was opened. Calculate the weight of a litre of air in the following way:

Weight of flask after admittance of air = ... grams
Weight of flask before admittance of air = ... grams
∴ weight of air admitted - - = ... grams

Volume of whole flask - - - = ... c.c.
Volume of water at bottom - - = ... c.c.
∴ volume of air admitted - = ... c.c.

∴ weight of ...... c.c. of air - = ... grams
∴ weight of a litre of air - - = ... grams

Does this result agree with that obtained in Exercise 58 *(b)*? Compare this result with those obtained by other students. Where this is not possible, repeat the experiment until you obtain two results which agree with one another.

* (*d*) Repeat the measurements of the last exercise, removing the air from the flask more completely by the use of the air pump. A Sprengel mercury pump, or a Geryk pump, is best; but in default of these an ordinary filter pump may serve the purpose. After you have weighed the flask when full of air and when empty, open its mouth under water, and thus measure the exact volume of air which has been extracted. In repeating the experiment, take care that the flask is quite dry before it is weighed.

59. The Expansion of Air.

(*a*) Fit a flask with a tightly-fitting rubber stopper, through which passes a glass tube at least 50 cm. long. Place the open end of the tube under the surface of the water in a basin, and gently heat the flask by moving the flame to and fro over all parts of it, so as to heat all parts equally (Fig. 41). Record what is the effect on the air in the flask. Take away the flame and notice what happens as the flask cools.

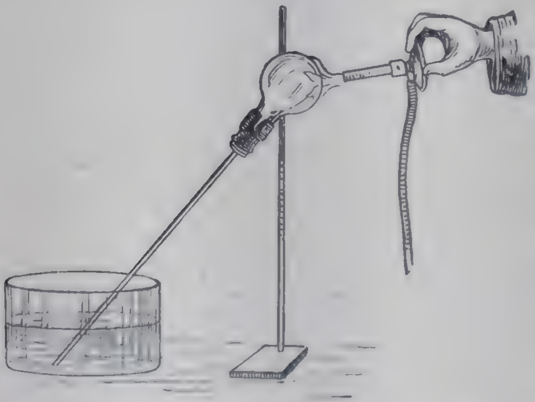

FIG. 41.—Heating the flask in Exercise 59 (*a*).

(*b*) Fit a 500 c.c. flask with a tightly-fitting rubber stopper pierced with two holes. Into one hole fit a thermometer, and into the other a short glass tube. On the glass tube fix a rubber tube and clip (Fig. 42). Place the flask in a saucepan or beaker of water, so that it is covered as far as the neck, and take off the clip. Heat the water in the saucepan until it boils. After it has been boiling for at least five minutes, note what the temperature is inside the flask, and close the clip. Take the flask from the saucepan or beaker and place it, mouth downwards, in cold water. Open the clip and allow the water to rush in. Shake the water round the flask. Close the clip, *taking care that the level of water is the same inside and outside the flask.* Measure the volume of water that has entered, and note the temperature of the water.

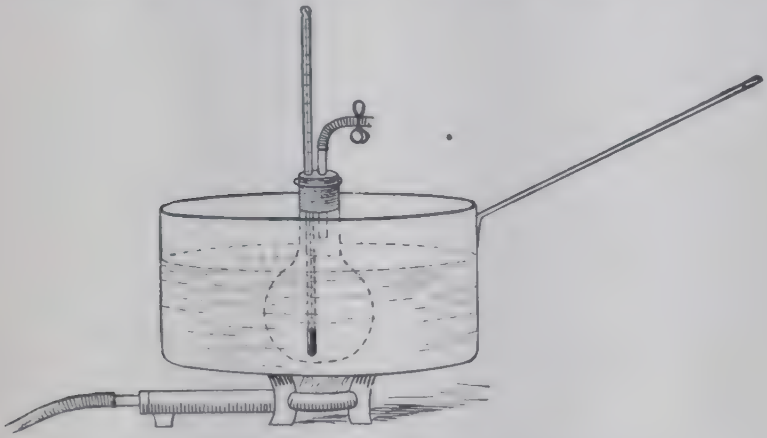

FIG. 42.—Apparatus for measuring the expansion of air.

Measure the total volume of water held by the flask when the stopper is in position. Calculate the expansion of air in the following way :

Volume of flask - - - - = ... c.c.
Volume of air which left the flask - - = ... c.c.

Final temperature of air - - - - = ... °C.
Temperature of water in which air was cooled = ... °C.
∴ temperature through which air was heated = ... °C.
∴ ...... c.c. of air when heated ...° C. expand ...... c.c.
∴ 1 c.c. of air when heated 1° C. expands ...... c.c.

Accurate observations have shown that all gases expand $\frac{1}{273}$ *of their volume at* 0° *C.* for each degree Centigrade through which their temperature is raised. They also contract the same fraction of their volume for each degree of temperature through which they are cooled below 0° C. These facts were discovered by Charles.

(*c*) Calculate what would be the volume at 273° C. of air which at 0° C. occupies one litre, if the pressure remained unaltered.

(*d*) What would be the theoretical volume of the same mass of air at −273° C., and the same pressure?

The temperature −273° C. is called the **absolute zero**, because it is believed that if a substance could be cooled to that temperature it would possess no heat whatever. At this temperature the volume of all gases theoretically becomes 0. All gases but one liquefy before this point is reached. The one exception would probably do so if it could be cooled sufficiently.

The volume of gases is therefore, as may be seen from the last example, directly proportional to the number of degrees their temperature is above the absolute zero, *i.e.* to their absolute temperature.

(*e*) Write down the absolute temperature of boiling water [Exercise 34 (*a*)], of melting sulphur [Exercise 36 (*g*)], of freezing mercury (−40° C.).

(*f*) Some coal gas measures 120 c.c. at 300° Absolute temperature. What will be its volume at 350° Absolute, if the pressure remains as at first? Let your calculation take the following form:

Volume of gas at 300° Absolute = 120 c.c.
∴ volume of gas at 1° Absolute = …… c.c.
∴ volume of gas at 350° Absolute = …… c.c.

(*g*) A flask holding 500 c.c. is filled with air at −23° C. What would be the volume of the air at 52° C. if it were free to expand under atmospheric pressure? Find the temperatures Absolute corresponding to the Centigrade degrees. Then carry out the calculation as in the previous exercise.

The temperature 0° C. has been chosen as the **standard** or **normal** temperature. When it is necessary to compare the volume of gases which have been measured at different temperatures, their volumes at 0° C. are first calculated.

(*h*) Calculate what the volume of the air in Exercise 59 (*g*) would become at normal temperature.

60. The Pressure of the Air.

(*a*) Refer to Exercise 59 (*a*). Try to decide what forces the water up the long tube when the air is cooling. Would the water be forced into the flask, no matter how long you made the tube?

*(*b*) Endeavour next to determine the height of water column which the pressure of the air would support if more of the air were removed from the flask. Obtain about 7 metres of narrow glass tubing and arrange it to form a double tube at least 3·5 metres long (Fig. 43). The cross piece joining the two long arms should be 20 cm. long. Connect the lengths of glass tubing with short rubber tubes. See that the ends of the glass tubing touch one another beneath the rubber connections. Fasten the tube on the wall, with the joining arm at the top. Place one end below the surface of water in a bowl (Fig. 43, *a*). To the other end attach a flask which

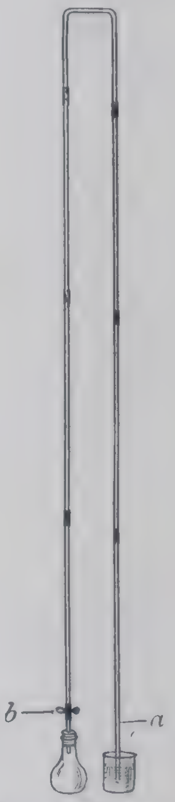

FIG. 43.—Apparatus for measuring the pressure of the air.

is fitted with a rubber stopper and short glass tube (Fig. 43, *b*).

Remove the flask for a moment and fit it with a short rubber tube and clip. Draw some air from the flask with your mouth and close the clip at once. The use of a piece of glass tubing will prevent the rubber tube from being closed by your lips in the act of withdrawing the air. Connect the flask again to the end of the long double tube (Fig. 43, *b*). Open the clip. Measure the height of the water column drawn from the bowl up the tube *a*. Close the clip again.

Determine the volume of air which has been withdrawn from the flask by opening its mouth under water and measuring the volume of water which enters. See that the water levels are the same inside and outside the flask. Finally measure, as in Exercise 59 (*b*), the total volume of air which the flask holds.

* (*c*) Calculate as follows the height of the water column which would be formed by withdrawing *all* the air from the flask :

Volume of flask - - - - - = ... c.c.
Volume of air withdrawn - - - - = ... c.c.
∴ percentage of air withdrawn - - = ...
Height of column when ...... % of air is withdrawn = ... cm.
∴ height of column when 100% of air is withdrawn = ... cm.

Compare these measurements with the results of other students. If you are working by yourself, repeat the work until results agreeing with one another are obtained.

(*d*) If all the air were withdrawn from the flask in the last experiment, how could you use the water column formed for measuring the pressure of the air? What disadvantages would there be in using such a column for the purpose? Suggest any arrangement you could use in its place.

(*e*) Prepare a more convenient apparatus for measuring the atmospheric pressure as follows:

Obtain a stout glass tube at least a metre in length. Clean it by pulling cotton wool through it. Seal one end by means of the blowpipe flame. Allow the tube to cool, and then fill it with mercury *over a mercury tray*. When it is quite full, close the end tightly with your thumb and invert it in a basin of mercury (Fig. 44).

Observe carefully what takes place. Decide what occupies the space above the mercury in the tube.

Clamp the tube in a vertical position, and fix by its side a metre scale, so that the first division of the scale is exactly level with the surface of the mercury in the dish. Note the height of mercury in the tube. Continue to take similar readings daily for a week, if possible. How do you explain the differences in the length of the column? What cause can you suggest for possible errors of measurement in the use of this apparatus?

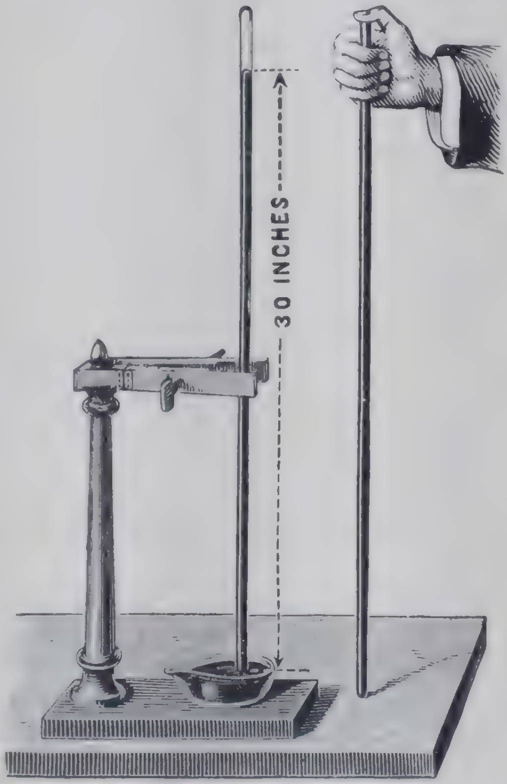

FIG. 44.—Mercury column used for measuring the pressure of the atmosphere.

(*f*) Examine the barometer in the laboratory in which you work. How does it differ from the apparatus you have made? Compare the readings of this barometer with those of the one you made for yourself. If there is any noticeable difference, suggest a possible cause for it.

61. The Effect of Pressure on the Volume of Gases.

(*a*) Obtain a burette. For the purpose of this experiment one fitted with a glass tap is best. The tap must be slightly greased to prevent leakage. Measure the volume of the ungraduated part at the bottom of the burette by passing in water from another burette.

Instead of the burette, a glass tube of about the same length and diameter may be used. It must be closed at one end.

Obtain a piece of thick walled rubber tubing not less than 2 metres long. An efficient substitute for this is ordinary rubber tubing enclosed in an outer linen cover, which can be made by sewing two lengths of tape together round the rubber tube.

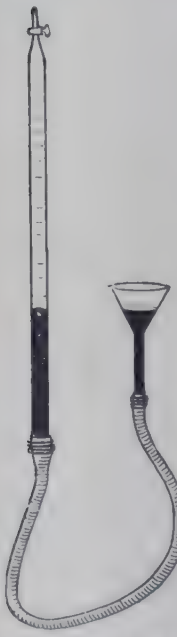

Fig. 45.—The effect of pressure on the volume of a gas.

Slip the rubber tube over the wider end of the burette or tube, and fasten it securely in this position with wire. In the other end of the tube secure a glass funnel in a similar manner. Clamp the burette or tube in a vertical position with tap or closed end uppermost (Fig. 45). Open the tap and pour mercury into the funnel until it half fills both burette and funnel. If the tube is used, tilt it and raise the funnel so as to let as much air as required pass out.

Close the tap of the burette. Fix by its side a metre scale. Raise or lower the funnel until the mercury level is exactly the same in funnel and burette. When this is the case, read the volume of air contained in the burette. Ascertain the height of the barometer column and write down in mm. of mercury the pressure acting on the air in the burette.

Raise the funnel until this pressure is doubled. After a few moments read the volume of the gas under these new conditions. What relation does it bear to the former volume?

Now lower the funnel until the pressure on the air is half what it was originally. Note the effect on the volume.

(*b*) Repeat this several times, altering the level of the funnel so that the mercury surface stands at different heights in funnel and burette. After each change of level, wait a few minutes Then note the volume occupied by the air in each case, and measure the difference in level of the mercury surfaces by means of a metre scale.

Record these observations in a table in the following manner:

HEIGHT OF BAROMETER. mm.	DIFFERENCE IN HEIGHT OF MERCURY COLUMNS. mm.	TOTAL PRESSURE IN TERMS OF MERCURY. mm.	VOLUME OF AIR IN BURETTE. c.c.	TOTAL PRESSURE × VOLUME.

(*c*) Multiply together the numbers which represent the total pressure and the resulting volume. Is the product the same in all the experiments? Express *in words* the fact that the product is constant.

(*d*) A more simple method for making similar measurements is as follows: Obtain a piece of thermometer tubing, with a bore of one millimetre, about 75 cm. long. Seal it at one end. Attach to the other end a glass funnel. Obtain some *clean* mercury. If the mercury is dirty, clean it by squeezing it through wash leather.

Clamp the tube in a vertical position with the open end upwards (Fig. 46). Fix by its side a metre scale. Pour some mercury into the funnel. In order to obtain a thread of mercury in the tube, procure a steel wire fine enough to enter the tube, and push it a little way down the tube. The mercury will be found to run down as far as the end of the wire.

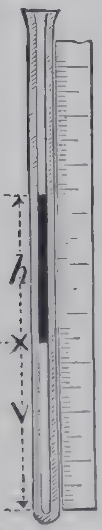

FIG. 46.—Apparatus used in Exercise 61 (*d*).

Express the total pressure on the volume of air thus enclosed, in mm. of mercury. Taking the length of the air column to represent the volume, find the variation in the volume of the enclosed air when the pressure is altered by introducing more mercury.

Find, by laying the tube flat on the table, the volume when the pressure of the atmosphere is acting alone on the enclosed air.

Invert the tube and clamp it so that the weight of the mercury thread acts in opposition to the atmospheric pressure. Obtain several readings with the tube in this position.

Draw up a table similar to that described in Exercise 61 (*b*). Compare the results with those you have already obtained.

(*e*) Express the results obtained in Exercise 61 (*b*) or (*d*) by means of a curve, plotting the pressure readings horizontally and the volumes vertically.

(*f*) Carry out similar measurements by means of the apparatus described in Exercise 61 (*a*), using coal gas in place of air. Place the results together in a table, and find whether the volume varies with the pressure in a similar way to air.

The facts which you have studied in this exercise were first discovered in the year 1662 by Robert Boyle. Your results may be expressed by the words "the temperature remaining the same, the volume of a gas varies inversely as the pressure placed on it."

(g) Find what would be the volume of the air used in Exercise 61 (*a*) if the pressure were equal to that of 760 mm. of mercury.

In order to compare the volumes of gases together, it is convenient to find what they would be at some **standard** or **normal pressure**. The pressure chosen as the standard is that of 760 mm. of mercury.

In the experiments you performed in Exercise 61 (*a*) and (*b*), the mass of air in the tube remained unaltered. The density of the air must therefore have increased as its volume became smaller. This fact is expressed by saying that "for the same temperature, the *density* of a gas is proportional to its pressure."

62. The Influence of Change of Pressure on the Boiling Point of Water.

The following experiment is due to Mr. H. E. Hadley. It was published in *The School World* (Feb. 1902).

(*a*) Fit a large flask with a rubber stopper, through which pass a thermometer and a tube bent twice at right angles (Fig. 47). The longer arm of the bent tube (Fig. 47 *C*) must be at least 25 cm. long, and its end must be drawn out slightly and cut off in a slanting direction.

Boil distilled water in the flask, and read the temperature recorded by the thermometer. Note the height of the barometer.

(*b*) Place the end of the tube *C* below the surface of 20 c.c. of mercury in a narrow cylinder. Take a reading of the thermometer after the steam has been issuing steadily for a minute. Measure the height of the mercury column from β to α (*i.e.* the difference in level of the mercury inside and outside the tube). Add this to the height of the barometer in order to obtain the total pressure in mm. of mercury.

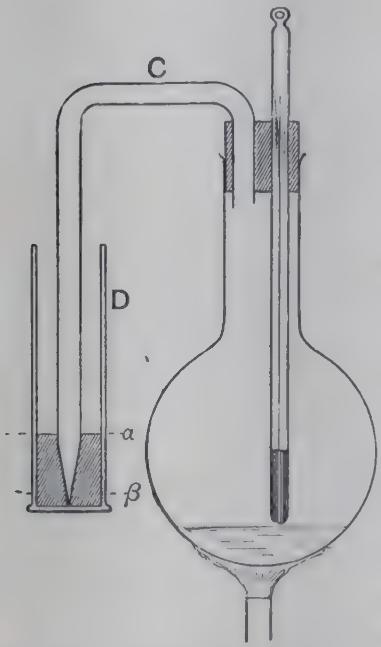

FIG. 47.- Influence of pressure on the boiling point of water.

(*c*) Repeat these observations with different depths of mercury in the cylinder.

(*d*) Turn the gas down so that the mercury stands higher inside than outside the tube. Does the boiling of the water cease?

After the mercury has stood at the same height in the tube for a minute, observe the temperature of the steam and the difference in level of the two mercury surfaces. Calculate the total pressure by subtracting this difference in level from the height of the barometer. Repeat the observations with the mercury at a different height in the inner tube.

(*e*) Collect these results into tabular form.

ATMOSPHERIC PRESSURE. mm.	DIFFERENCE IN LEVEL. mm.	TOTAL PRESSURE. mm.	TEMPERATURE OF STEAM.

ADDITIONAL EXERCISES. X.

1. Given that mercury has a density of 13·6, calculate the height of the water column that would be supported by the air on a day when the barometer reads 760 mm. Compare this with the value you obtained in Exercise 60 (*c*).

2. Determine the actual height of a water column supported by the air, using the following apparatus. Obtain a piece of lead or composition tubing about 9 metres long. To one end attach two metres of glass tube. Place the other end of the lead pipe beneath the surface of water in a bowl. Withdraw the air from the tube by means of an air pump attached to the glass tubing.

> A filter pump in good working order will serve to exhaust the tube, but a Sprengel or Geryk pump is better.

When all the air has been removed and the tube is full of water, close the glass tube by means of a screw clip and disconnect from the pump. Now fasten the tube in a perpendicular position to the wall of the class room, or if that is not high enough, to an outside wall, still keeping the open end of the tube below the surface of the water. What happens to the water in the tube?

Measure the height of the column from the surface of the water in the bowl, taking care that it is the perpendicular height which is being measured.

Compare the actual height with that which you found by calculation in Exercise 60 (*c*).

3. Calculate the height at which the glycerin barometer would stand on the day on which you are working. The density of glycerin is 1·26.

4. Use the apparatus described in Exercise 61 (*a*) or (*d*) to find the pressure of the atmosphere. Measure the volume of gas contained, (i) at the atmospheric pressure,

and (ii) at some other pressure, which is a known amount greater or less than the atmospheric pressure at the time. Then, by a simple algebraical equation, calculate the pressure of the atmosphere.

5. A certain mass of air at 49° C. and 780 mm. measures 200 c.c. What would be its volume at normal temperature and pressure?

6. How must the pressure be altered in order to make air twice as dense as at atmospheric pressure?

CHAPTER XI.

A STUDY OF THE RUSTING OF IRON.

63. The Cause of the Rusting of Iron.

(*a*) Write down what you consider to be the causes of the rusting of iron. What substance would you use in order to make a piece of iron rust?

(*b*) Place some iron nails in a corked bottle full of water, and leave them for at least a day.

At the same time place some more nails on an open watch glass and wet them. Leave these for the same length of time as you do those in the bottle.

At the end of this time examine the nails in the bottle and those on the watch glass and decide which have rusted more. Does this suggest that water *alone* is the cause of iron rusting?

(*c*) Make a muslin bag and fill it with iron filings.

> In order to remove any grease from them, the iron filings used in this and the following exercises must be previously washed in boiling methylated spirit, and then dried.

Obtain a gas jar or cylinder and a piece of glass rod just long enough to reach from the mouth of the jar to the bottom. Tie the bag of filings to the end of the rod after having soaked the filings and bag in water. Obtain a dish containing water several inches deep. Place the gas jar mouth downwards in the water, with the bag of iron filings supported above the water in the jar (Fig. 48). Notice the height at which the water stands within the cylinder.

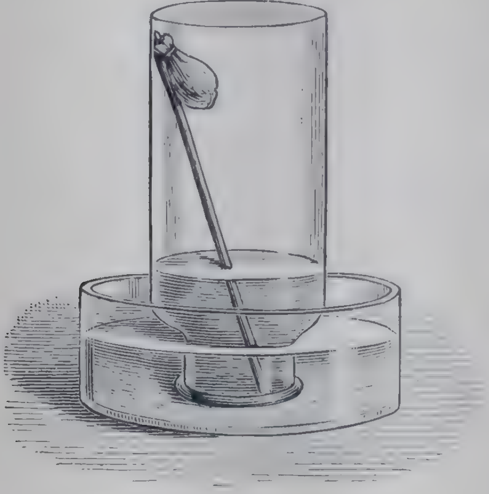

FIG. 48.—Iron rusting in air.

After the lapse of a day examine the cylinder. What change do you find has taken place? What substance—do you learn from this Experiment—takes some part in the rusting of the iron filings?

(*d*) Repeat the last exercise, placing double the quantity of iron filings in the bag. Is more of the air used up? Ascertain as nearly as you can what percentage of the air has disappeared.

(*e*) Try to decide for yourself where the used up air can have gone. Ascertain if the water contains more gas than usual in solution, by boiling the dissolved gas out of it, and collecting it.

(*f*) Where else may the air possibly have gone?

(*g*) Weigh some iron filings on a watch glass and with them a piece of stout copper wire for use as a stirrer. Damp the filings and leave them in the air till they are covered with rust. Stir them with the wire so as to expose fresh surfaces to the air, taking care not to dislodge any of the filings in the process. Leave them for at least a day. Finally weigh them and find if there has been any change of weight during the process of rusting. State the conclusion you now draw as to where the air used up in the process of rusting has gone. Is the rusting of iron a physical or a chemical change?

64. The Effect of Rusting on Air.

(*a*) Examine the air left behind in a cylinder in which iron has rusted. Hold a lighted taper in the jar. Does it behave as it would in ordinary air?

The gas left in the cylinder will be called "inactive air" until we learn more about it.

(*b*) In order to study "inactive air," prepare it in larger quantity by allowing iron filings to rust in a larger volume of air. Fit a large wide-mouthed bottle with a well-fitting rubber stopper and two tubes as shown in Fig. 49. Place rubber connections on these tubes. Close one by means of a clip; attach to the other a long tube bent at right angles (Fig. 49, *b*). Put the end of this tube in a vessel containing enough water to fill a third of the bottle. The tube must reach the bottom of the water.

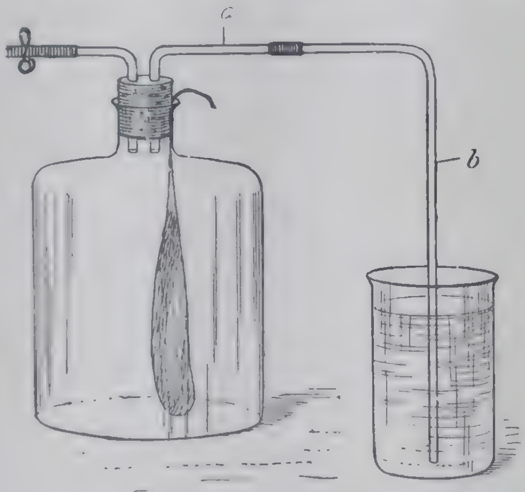

FIG. 49.—The preparation of "inactive air."

Hang inside the bottle a long muslin bag of iron filings in such a way that any water entering by tube *c* must drip on the bag and keep it moist. Allow the iron to remain in the bottle four or five days. Mark the height to which the water has then risen in the bottle. When the flow of water into the bottle ceases, it may be concluded that the filings cannot remove any more of the air. The "inactive air" may be forced from the bottle as required by connecting one of the tubes to the tap and letting water enter the bottle.

(*c*) Compare the smell, taste, and appearance of "inactive air" with those of ordinary air. Do they differ in any way? Find out whether any combustible substance will burn in "inactive air."

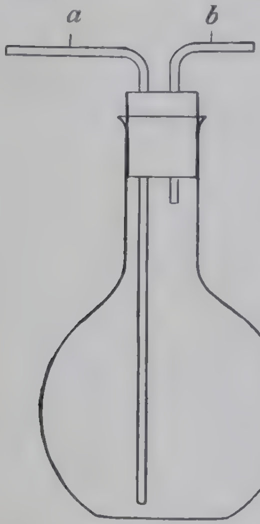

FIG. 50.—Flask used for determining the density of gases.

(*d*) Measure the density of "inactive air" in the following manner. Obtain a flask, holding about 500 c.c., with a well-fitting rubber stopper. Fit the flask with two tubes as shown in Fig. 50. Find the weight of the flask and its fittings. Attach the longer glass tube (Fig 50, *a*) to the bottle of "inactive air" (Fig. 51, *a*), and pass "inactive air" through the flask. In order to make certain that all the ordinary air has been swept out of the flask (Fig. 51, *b*) collect over water the gas as it leaves the flask (Fig. 51, *c*). When about 2 litres of gas have been thus passed through the flask, you may know that the air in the flask has been mostly replaced by "inactive air."

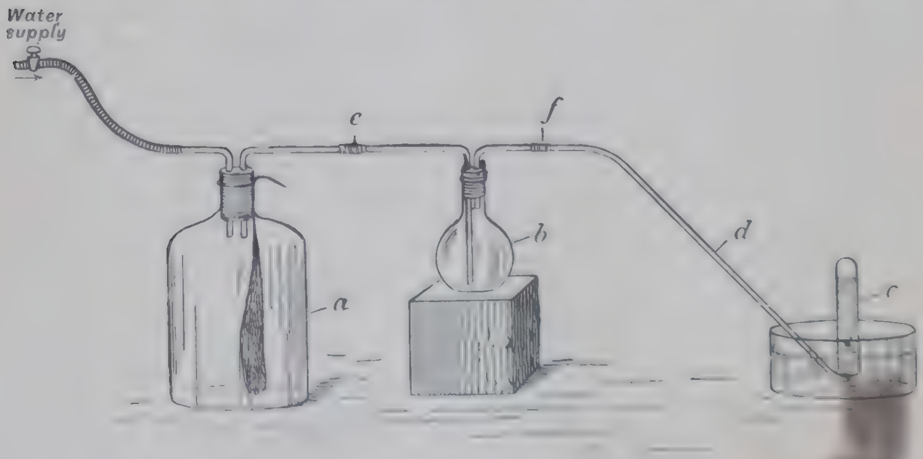

FIG. 51.—Filling the flask with "inactive air" in Exercise 64 (*d*).

Close the clips at (*e*) and (*f*) (Fig. 51). See that the clips on the bottle of "inactive air" are left closed. Weigh the flask and its contents. Find the exact volume of gas held by the flask by measuring the volume of water which fills it up to the point occupied by the stopper. Note the height of the barometer and the temperature of the room.

> All substances lose weight when suspended in air, as they do when weighed in water [Exercise 25 (*a*)] The flask used in Exercise 64 (*d*) displaces much more air than do the weights, and therefore seems lighter than it really is. The error may be greater than the whole weight of gas taken.
>
> It can be corrected by adding the weight of air displaced to the result obtained whenever the flask is weighed. This correction is the same in amount so long as the density of the atmosphere remains the same. It may be omitted altogether, provided the weighings are completed on the same occasion, while the temperature and pressure of the air are unchanged.

Calculate the weight of air held by the flask, and hence by subtraction the weight of the flask itself. Finally calculate the density of "inactive air."

Weight of 1 litre of air at 0° C. and 760 mm. - - - - - - = 1·29 grams

Volume of gas contained by flask at ...° C. and ... mm. - - - = ... c.c.

Volume of gas, corrected to 0° C. and 760 mm. - - - - - = ... c.c.

Weight of this volume of air at 0° C. and 760 mm. - - - - - = ... grams

Apparent weight of flask and air - - = ... grams
Weight of air in flask - - - - = ... grams
∴ apparent weight of flask alone - = ... grams

Apparent weight of flask filled with "inactive air" - - - - - = ... grams
Apparent weight of flask alone - - = ... grams
∴ weight of "inactive air" - - = ... grams

∴ ...... c.c. of "inactive air" at 0°C. and 760 mm. weigh - - - ...... grams
∴ 1000 c.c. of "inactive air" at 0°C. and 760 mm. weigh - - - ...... grams

*(*e*) Determine the solubility in water of inactive air in the following manner. Obtain two flasks, each holding about a litre. Procure for them tightly fitting rubber stoppers and tubes (Fig. 52). Place clips on the tubes and connect the flasks as shown in Fig. 52. Measure the volume contained by the flask *A*.

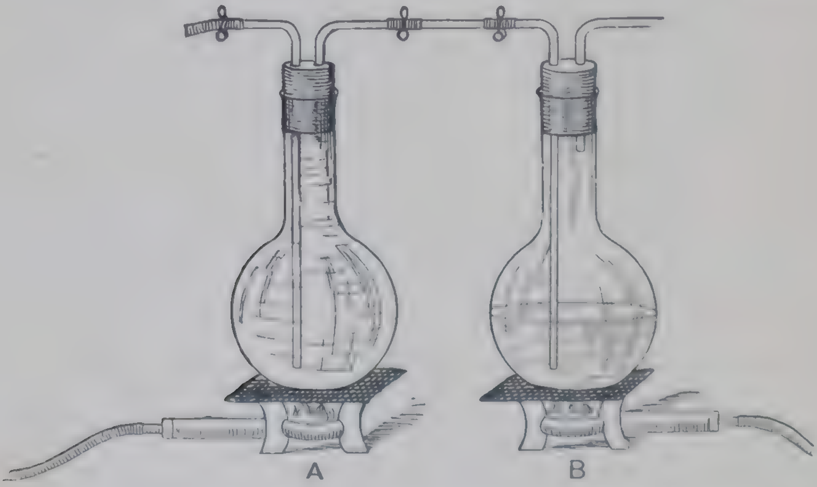

FIG. 52.—Filling the flasks in Exercise 64 (*e*) with water free from air.

The flasks must first be filled with water free from air. Fill the flask *A* to the top, the flask *B* half way with water. Open the two clips between the flasks and boil the water in both. Open the longer tube of *A* once during the boiling to allow any air collected in it to escape. Remove both flames. When the water has cooled to the temperature of the air, connect the bottle containing the "inactive air" [Ex. 64 (*b*)] to the longer tube of *A* and pass the gas through both flasks for a quarter of an hour. Both now contain a saturated solution of "inactive air."

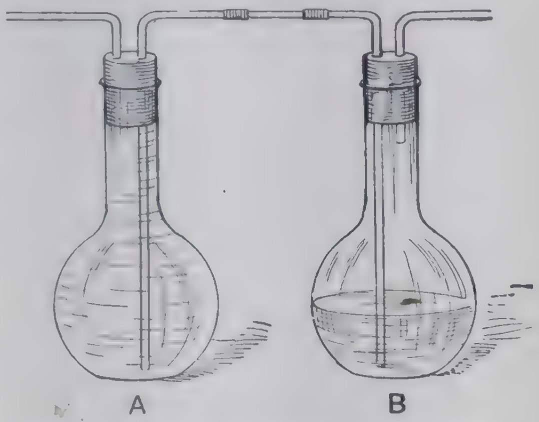

FIG. 53.—Expelling bubbles of "inactive air" from flask *A*.

If any bubbles of "inactive air" have collected in the neck of the flask *A*, disconnect the flasks and connect them as in Fig. 53. Then with your lungs force some of the solution from *B* into *A*, until the latter is quite full of liquid.

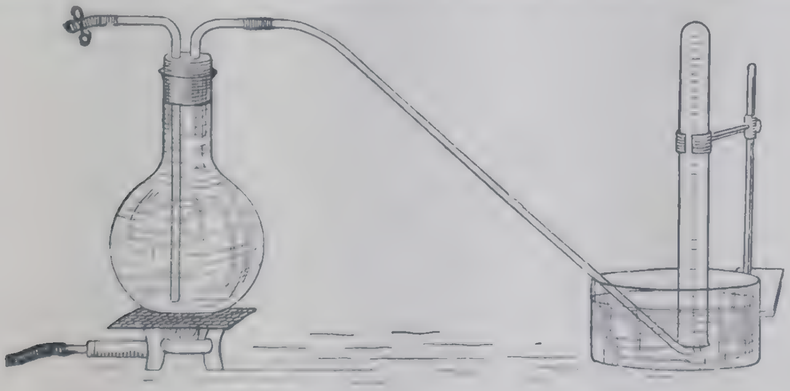

FIG. 54.—Collecting the "inactive air" dissolved in flask *A*.

It now remains to measure the volume of gas dissolved in the flask *A*. For this purpose connect a delivery tube to the flask as shown in Fig. 54. The delivery tube must be full of water when connected, or the air it contains will be measured as having come out of the water in *A*. Boil the solution and collect the "inactive air" which is expelled in a graduated tube. Calculate as in Exercise 31 (*c*) the volume of gas in every 100 c.c. of solution.

(*f*) Draw up in tabular form a comparison of the properties of "inactive air" and ordinary air.

	AIR.	"INACTIVE AIR."
Colour - - - - -		
Taste and Smell - - -		
Weight of 1 litre - - -		
Solubility in 100 c.c. of water		
Effect on burning taper -		

65. The Proportion of "Inactive Air" Present in the Atmosphere.

(*a*) Arrange the apparatus used in Ex. 63 (*c*) to discover the proportion of inactive air in the atmosphere. When the rusting has no further effect on the air, measure the volume of water which has entered the bottle. Find also the volume of air originally contained by the bottle. From these results calculate the volume of "inactive air" contained in 100 c.c. of air.

Volume of air used in the rusting, - = ... c.c.
Volume of air contained by bottle - = ... c.c.
∴ volume of "inactive air" in ...... c.c. of air = ... c.c.
∴ volume of "inactive air" in 100 c.c. of air = ... c.c.

*(*b*) In order to obtain in another way the same measurement, seal one end of a glass tube about 1·5 cm. in diameter and at least half a metre long. Damp the interior of the

tube and then sprinkle in iron filings. Place the tube mouth downwards in water, deep enough to immerse one-third of its length. Mark the position of the water surface while holding the tube so that the water level is the same inside and outside the tube. Allow the tube to stand until after an interval of half a day there is no *further* rise of water within the tube. Lower the tube in the water or, if necessary, pour water into the trough until the water level inside and outside the tube is again the same. Mark this level also.

By measuring the volume of the tube down to the first mark, find the volume of air present at first. In a similar manner, by measuring to the second mark, find the volume of "inactive air" which remained.

Calculate the percentage volume of "inactive air" present in ordinary air and enter your results in the manner shown at the end of Ex. 65 (*a*).

Compare the number with the value obtained in Ex. 65 (*a*).

ADDITIONAL EXERCISES. XI.

1. Collect the air dissolved in water by boiling tap water in a large tin can. The can must be quite full [Ex. 31 (*c*)]. Allow iron filings to rust in this air, and find what change of volume occurs. Calculate what percentage this is of the volume of air taken. Compare the number thus obtained with the percentage of "inactive air" present in ordinary air. Can you account for the difference?

2. Discover if any part of coal gas can be removed by leaving iron filings to rust in it. If the coal gas is reduced in volume, discover what percentage is removed.

CHAPTER XII.

A STUDY OF BURNING.

66. Do Substances Change in Weight when Burnt?

(*a*) Procure some brown paper and cut from it a piece 2 inches square. Weigh a small crucible. Fold the paper so that it will stand upright, place it in the crucible and weigh both. Record your weighings thus:

Weight of brown paper and crucible = ... grams
Weight of crucible alone = ... grams
∴ weight of paper = ... grams

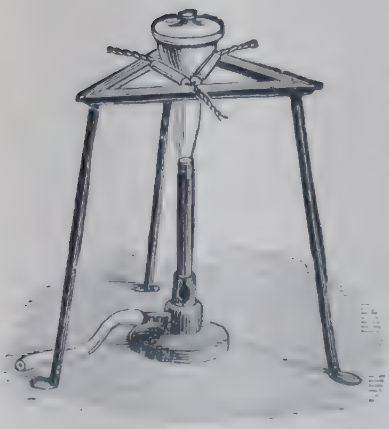

Fig. 55.

Support the crucible over a Bunsen flame by means of a pipeclay triangle and tripod stand (Fig. 55). Heat it from below till the paper begins to char. Then with the flame light the paper at one corner and rekindle it in the same way as often as it goes out, until it has burnt to an ash. Let it cool and weigh it again. Enter your results as follows:

Weight of crucible and paper before burning = ... grams
Weight of crucible and paper after burning = ... grams
$\therefore \left\{\begin{matrix}\text{loss}\\ \text{or gain}\end{matrix}\right\}$ of weight = ... grams

Calculate the gain or loss in weight per 100 grams of the paper as follows:

$\therefore \left\{\begin{matrix}\text{loss}\\ \text{gain}\end{matrix}\right\}$ in weight of ...... grams of paper = ... grams.

$\therefore \left\{\begin{matrix}\text{loss}\\ \text{gain}\end{matrix}\right\}$ in weight of 100 grams of paper = ... grams.

Write exactly all you observed in the course of the burning.

(*b*) Cut a piece of wood into chips. Weigh a crucible, first alone, and then with the wood. Write down the weights as you did those in the preceding exercise. Heat the wood from below until it begins to char; then light it with the flame. Continue to heat until a very small quantity of white ash is left. When the crucible is cool weigh it with the ash it contains. Record the result of the weighing in a way similar to that used in the previous experiment. Note also whether any smoke was formed during the heating.

(*c*) Weigh a crucible lid. Obtain some phosphorus. Place on the inverted crucible lid a small piece of phosphorus which has been carefully dried in blotting paper, and find the weight of both.

> CAUTION.—*Phosphorus so easily catches fire that it must always be cut under water and must never be touched with the fingers.*

Remove the phosphorus to the draught cupboard and set light to it with a warm wire. Notice how easily it burns. When it is cool weigh it again on the lid and discover the change of weight. Calculate the amount of this change per 100 grams of phosphorus.

(*d*) Weigh a crucible lid and a piece of stout copper wire (for use as a stirrer). Place a few pieces of lead on the lid and weigh again. Support the lid on a pipeclay triangle over a Bunsen flame and note carefully the changes which occur to the lead. What forms on the surface of the lead? Use the stirrer to keep the surface of the lead bright, but be careful not to remove anything from the lid in so doing. When no more bright lead seems to be left, let the lid and its contents cool, and weigh them together with the stirrer. Calculate any change in weight as a percentage of the weight of lead taken.

(*e*) Cut a piece of thin copper wire (No. 40) 100 cm. long. Weigh it in a crucible the weight of which you have found already. Then heat it for half an hour in the muffle furnace. Allow it to cool and again weigh. Calculate from these weights the gain or loss per cent. of the copper.

(*f*) Obtain a short piece of glass tube. Clean it and dry it carefully. Find its weight. Heat it in the Bunsen flame till the end is quite soft. Let it cool and weigh it again. Find what change of weight has occurred. Is the change of the glass when heated chemical or physical?

(*g*) Collect the results of the last six exercises into a table:

SUBSTANCES WHICH DO NOT CHANGE IN WEIGHT WHEN BURNT.	SUBSTANCES WHICH GAIN IN WEIGHT WHEN BURNT.	SUBSTANCES WHICH LOSE IN WEIGHT WHEN BURNT.

(*h*) Underline in these columns the names of the substances which smoke while burning. In which column do they all occur? What conclusion can you draw from this?

67. The Cause of Loss of Weight in Burning.

(*a*) In order to test the theory that substances which lose in weight during burning do so because they lose the smoke that is formed, find the effect of heat on magnesium, a substance the smoke from which can easily be caught. First take in the crucible tongs a piece of magnesium ribbon about half an inch long. Light the end of it in a flame. Observe carefully what takes place while it burns.

(*b*) Weigh a crucible lid. Invert it and place on it a few pieces of magnesium ribbon each half an inch long. Weigh magnesium and lid together. Find the weight of the ribbon by subtraction. Do not take less than half a gram of magnesium. Support the lid over a Bunsen flame by means of a tripod and pipeclay triangle. Heat the magnesium from below till it takes fire. Continue to heat until all is burnt. When it is quite cool, weigh lid and contents again. Calculate the loss or gain in weight for a hundred grams of magnesium.

(*c*) Weigh a crucible and lid first alone, then with rather more than half a gram of magnesium ribbon. Take off the lid. Heat the crucible with a Bunsen flame until the magnesium takes fire. Immediately after this happens, replace the lid on the crucible, in such a way as to allow the burning to continue, while as little as possible of the smoke is allowed to escape. This can be done if part of the crucible mouth is left open and only closed when the fumes begin to escape. When the magnesium no longer burns brightly and no more fumes are formed, remove the lid altogether and heat with a full flame for five minutes. When the crucible is quite cool, ascertain its weight. Calculate from the numbers thus obtained the loss or gain in weight per hundred grams of the magnesium.

(*d*) Compare the result obtained in the preceding exercise with those obtained in Exercise 67 (*b*). What reason can you give for the great difference? Has not the loss of smoke in the latter case something to do with the difference in the results?

CAUTION.—*Read over again in Exercise 65 (c) the precautions to be taken in the use of phosphorus.*

(*e*) Refer to Exercise 65 (*c*), and find what effect burning has on the weight of phosphorus. Burn a small piece of phosphorus on a crucible lid, placing over it a dry bell jar. Perform this experiment in the draught cupboard. What happens to the fumes when they are left for some time without the bell jar being moved? Can you suggest any method by which all the fumes from burning phosphorus can be caught and weighed?

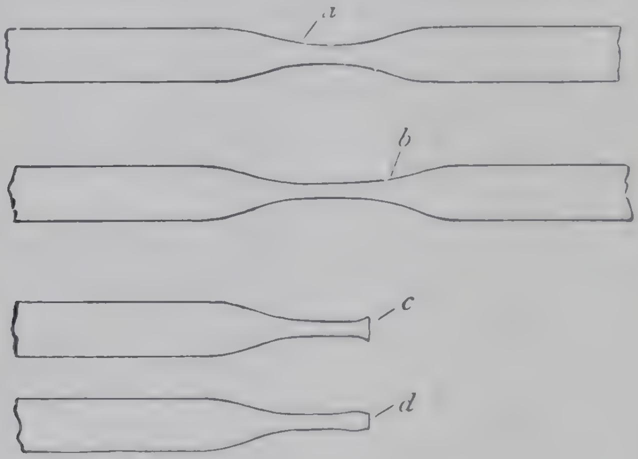

FIG. 56.—Preparation of the tube for Exercise 67 (*f*).

(*f*) Make the following arrangements to allow of the burning of phosphorus in such a way that all the fumes may be caught. Cut off 30 cm. of hard glass tubing, with internal diameter of 1 cm. Draw it out so as to form a tube of about half the diameter at one end. To do this, first heat it about 5 cm. from one end in the blowpipe flame, without air, until the tube is covered with soot. Then begin to work the bellows slowly. Increase the pressure of air gradually until a blue flame is obtained. Turn the tube round constantly while this is being done so as to heat it equally on all sides. When it is soft, take it from the flame and pull it out gently until the bore is reduced to about half its former size (as in Fig. 56, *a*). Hold the tube in the luminous flame until it is again covered with soot.

Then heat the tube again at the point (Fig. 56, *a*) where the contraction begins, and again remove it from the flame and draw it out slightly. When it is cool make a scratch on it with a file and break it at such a point (Fig. 56, *b*) as to leave the end as shown in Fig. 56, *c*. Heat the end of the tube, first in the flame without air, later more strongly, turning it round, till it falls in slightly (Fig. 56, *d*). Pack about two inches of the narrow end of the tube with a layer of asbestos fibre, so as to allow the passage of air. Attach the drawn-out end of the tube to an aspirator so that air may be drawn through from the open end of the tube (Fig. 57). Prepare a second plug of asbestos to fit loosely into the open end of the tube.

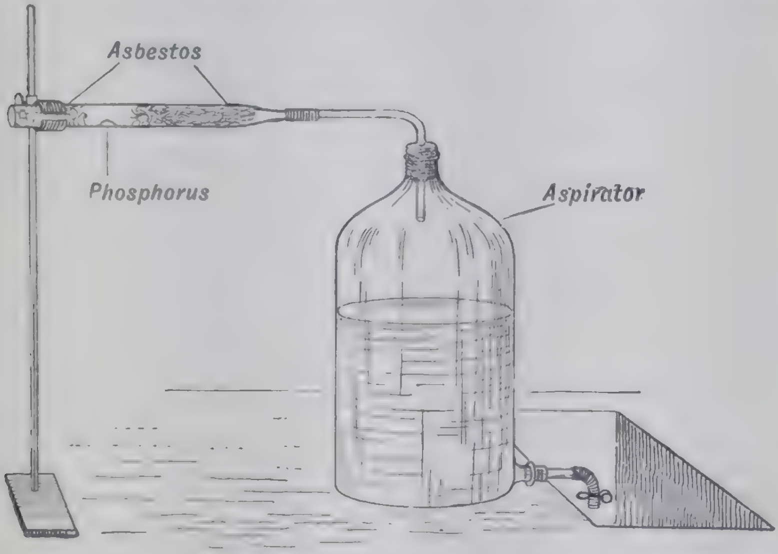

Fig. 57.—Phosphorus burning in a current of air.

Dry both tube and asbestos thoroughly by warming them slightly and blowing air through with the bellows. When the tube is perfectly cool again, cut a small piece of phosphorus, dry it between blotting paper, and place it in the tube between the asbestos plugs. Weigh the tube and its contents. Attach the narrow end of the tube to the tube from the aspirator. Start a gentle current of air passing through the tube, and heat the phosphorus gently until it burns. The stream of air must now be regulated so that the burning just continues but no fumes are drawn through the asbestos. If fumes are seen passing through the asbestos, check the rate at which air is passing, and by that means let the phosphorus burn more slowly. When the combustion is complete, let the tube and its contents cool and then weigh them. What change is there in the weight? Compare this result with what you found in Exercise 66 (*c*), and endeavour to explain the difference between these results. How does this explanation agree with the conclusions you came to from a study of magnesium. Keep the tube and contents for use later in the chapter.

(*g*) Refer to the table drawn up in Exercise 66 (*g*), and find an explanation of the facts recorded there.

68. The Gain in Weight during Burning.

(*a*) How can you explain the increase in weight of burning substances which has been observed? From what sources can the substances have gained the weight? Write down your suggestions.

CAUTION.—*Read over again the precautions to be observed in using phosphorus, given in Exercise* 66 (*c*).

(*b*) Place a dried fragment of phosphorus on a crucible lid. Float the lid on the surface of water contained in a dish. Remove the stopper from a bell-jar, and cover the phosphorus with the bell-jar. The sides of the bell jar must stand at least two inches deep in the water in the dish. Mark how high the water comes up the side of the jar. Set light to the phosphorus with a warm glass rod or piece of wire, and immediately place the stopper tightly in the mouth. Observe carefully what takes place. What indication does this give as to the source from which the phosphorus obtains the gain in weight?

> CAUTION.—*Before beginning the next exercise, read it through, taking special notice of the sentences in italics.*

(*c*) Obtain a test tube and a rubber stopper which fits it tightly. Dry the tube thoroughly by warming it and blowing air into it. Weigh the test tube and stopper approximately. Leaving the weights still on the pan, cut a piece of phosphorus about the size of a pea and dry it with blotting paper. *Remember to handle the phosphorus with great caution.* Drop the phosphorus into the test tube, and replace the stopper as firmly as possible. Obtain the exact weight of the tube and phosphorus as quickly as possible. If much time is lost in the process of weighing, and the room happens to be warm, the phosphorus may take fire before you have found the weight. Take the test tube in your hand so that you can hold the stopper firmly in position, and at the same time can turn the tube above a flame. Warm very gently *the parts of the tube which do not touch the phosphorus. As soon as you see the phosphorus begin to burn, hold the tube under a bench or table, away from eyes and face.* When the burning is over and the test tube quite cool, weigh it again without removing the stopper.

Notice what has happened to the fumes now that the tube is cool. What conclusion must you form as to the result of the experiment on the weight of the contents of the tube? Keep the stopper tightly in its place and proceed to the next exercise.

(*d*) Make a file scratch on the tube to mark how much space was occupied by the stopper. Hold the test tube mouth downwards under water and take out the stopper. Note exactly what happens. Replace the stopper while the water stands at the same level inside and outside the tube. Measure the volume of water which has entered the tube.

Find also the volume of water contained by the whole tube when the stopper is in the position it occupied during the experiment. Thus measure the volume of air which the tube must have contained at the beginning of the experiment, and also the volume used up during the burning. From these results calculate the percentage of air which has been used.

(*e*) What percentage of air was left behind in the last exercise? Compare this percentage with the result obtained in Exercise 65 (*a*). Does not this suggest that the same part of the air is left behind as when iron rusts? Use any other tests you can think of to find if this is actually the case. In order to study the properties of this air left behind when phosphorus is burnt, prepare it in larger quantity by burning phosphorus over water beneath a bell jar, as you did in Exercise 68 (*b*).

(*f*) Draw up a table similar to that in Exercise 64 (*f*), comparing the properties of the gas left behind when phosphorus is burnt with those of "ordinary air," and of "inactive air." Decide for yourself whether the gas formed after burning phosphorus in air is the same as "inactive air."

(*g*) In a similar way burn, under a bell-jar, paper, a candle and other combustibles. Find what you can about the air left behind. Compare it, by writing your results in tabular form, with that left behind when phosphorus burns.

> On account of its being found in the substance "nitre," the name **nitrogen** was given to the gas hitherto called "inactive air." By this name it will be called in future.

*(*h*) Allow phosphorus to "rust" in air. Procure the long tube used in Exercise 65 (*b*) and a piece of copper wire of about the same length. Fix a piece of phosphorus to the end of the wire by bending the wire so as to form a small cage. Pass the phosphorus into the tube at the end

of the wire. Place the tube mouth downwards in a cylinder containing water (Fig. 58). Determine the exact proportion of air removed by the phosphorus, when after the lapse of a day there is no further decrease in the volume of the air.

69. The Products formed when Substances Burn in Air.

(*a*) Write down what you consider to be the nature of the products formed from paper and wood when they burn in air.

(*b*) Describe as nearly as you can the products formed by the burning of phosphorus, copper, and magnesium. How do they differ from those of paper and wood?

(*c*) Examine the substance which you prepared by heating lead in the air. Compare it with the substances litharge and red lead, which are manufactured from lead in a similar way, by roasting it in air.

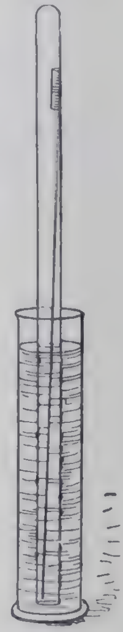

FIG. 58.
Phosphorus "rusting" in air.

> **Litharge** is manufactured from lead by roasting it in the air. After continuous roasting for some days, the litharge gradually changes to **red lead.**

70. The Separation of the Air used in Burning.

(*a*) Think out and write down the answers to the following questions:

(i) Where does that part of the air go which disappears when substances burn?

(ii) What kind of substances do you think take it in when it disappears?

(iii) What properties do you think this part of the air must have?

*(*b*) In order to find out for yourself exactly what takes place during the manufacture of litharge and red lead, make a study of the behaviour of these two substances when heated in air. Obtain two stout iron plates, and on them place thin layers of litharge and red lead. Leave a margin of an inch at the edge of the plates so that there is no risk of a part of the powder falling off and being lost. Find the exact weights of the plates and powders. Heat them for several hours by means of Fletcher burners, the red lead being heated more strongly than the litharge. Allow them to cool and weigh them again. Repeat the heating and weighing until some marked change of weight occurs. What conclusion do you come to from this change of weight? Try to connect this change of weight with the change from litharge into red lead, and from red lead into litharge.

(*c*) Place in the bottom of a hard glass tube as much red lead as you can get on the point of a knife blade. Heat it gently in the Bunsen flame. Then allow it to cool. Observe carefully what colour change there is. Heat the tube again gently and again allow it to cool. Do the first changes of colour repeat themselves? Do you consider this a chemical or a physical change?

Now heat the tube more strongly. Examine the substance left behind when the tube has cooled. Do you consider it to resemble red lead or litharge? Is this a chemical or a physical change?

(*d*) Obtain the apparatus used in Exercise 49 (*f*). Half fill the tube with red lead. To the open end fit a delivery tube leading below the surface of water contained in a bowl. Arrange the tube so that the red lead can be heated with a Fletcher burner (Fig. 59).

Heat the red lead and collect the gas which comes from it in an inverted boiling tube full of water. What are the first bubbles of the gas probably composed of? Allow the first tubeful collected to escape. When another tube has been filled with the gas, close its mouth with a glass plate. Raise it from the water, mouth upwards, and lower into it a lighted match. Blow out the flame and plunge the glowing end of the match again into the tube. What indication have you that this gas is the active part of the air of which you are in search?

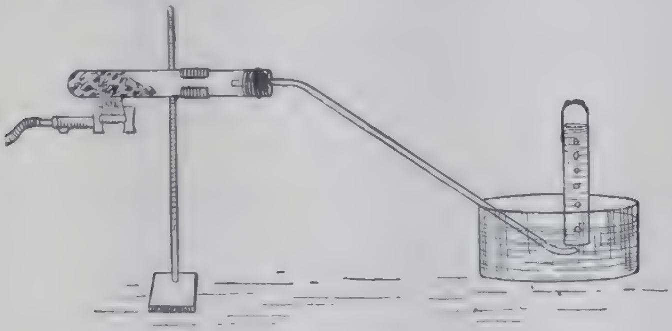

FIG. 59.—Collecting the gas formed when red lead is heated.

(*e*) In order to see if this gas is the same as the part of the air used up during the rusting of iron filings, allow a small muslin bag of filings to rust in a tube full of this gas. Arrange that the bag shall be as nearly as possible at the top of the tube. After the lapse of several days, what do you find has taken place? Is nearly all the gas used up? What evidence have you that the gas prepared from red lead is the same as that removed from air when iron rusts in it?

(*f*) As a final proof that this gas is the active part of the air used up during rusting and burning, prepare *ordinary air* from the two gases into which you have separated it. Leave iron filings to rust in a tube containing ordinary air. Mark the height of the water inside the tube so that you know the volume of air originally present. After the usual portion has been removed, make up the air to its original volume with the gas prepared from red lead. Find if this mixed gas differs from ordinary air. Does it behave like ordinary air to a burning match, and to a glowing splinter?

71. The Active Part of Air.

(*a*) In order to prepare this "active air" in quantity, heat a mixture of two substances, potassium chlorate and pyrolusite.

> Potassium chlorate is an artificially prepared substance used in the manufacture of safety matches; pyrolusite is a mineral which is found in considerable quantities naturally. Both substances are rich in the gas you are about to prepare.

Powder the potassium chlorate in a mortar and stir with it the pyrolusite. Prepare an apparatus like that shown in Fig. 59. Half fill the hard glass tube with the mixture just made. Heat the tube gently, moving the flame constantly so as to heat the tube as much in one part as another. Reject the first tube of gas that is collected. Then fill a large gas jar or bottle, fitted with two tubes as in Exercise 64 (*b*), with the gas.

For this purpose fill the bottle with water. Replace the stopper. Connect one tube to the tube which is delivering the "active air." Invert the bottle and allow the water, as it is driven out by the "active air," to run into the sink

(*b*) Find the weight of one litre of the gas, as you did that of nitrogen. Read over the precautions given in Exercise 64 (*d*). Collect the gas which passes through the density flask until it rekindles a glowing splinter. You can then consider the air driven out.

*(*c*) Measure the volume of the "active air" that dissolves in 100 c.c. of water at the atmospheric temperature, using the apparatus and method described in Exercise 64 (*e*).

(*d*) Draw up a table similar to the one you made in Exercise 64 (*f*), in order to compare the properties of air, "active air," and "inactive air."

(*e*) By means of the results here collected show that the properties of ordinary air are such as might be expected in a mixture of "active" and "inactive" air.

72. The Products formed by Burning in "Active Air."

(*a*) Describe the product obtained by the burning of magnesium in air. Obtain a gas cylinder. Fill it with water and invert it in water in a trough. Displace the water with gas from the bottle full of "active air" [Exercise 71 (*a*)]. Place a ground glass plate over the mouth of the cylinder and take it from the water. Take a piece of magnesium ribbon 10 cm. long in the crucible tongs. Light the end and introduce it into the cylinder full of active air, taking care not to touch the sides of the cylinder with the burning substance. What do you observe? Examine carefully the substance formed during the burning. Does it appear to differ from that produced when magnesium burns in air?

*(*b*) Procure a deflagrating spoon—a small iron cup fixed to the end of a long handle (Fig. 60). Place in it a small fragment of wood. Fill a cylinder with the "active air" as in Exercise 72 (*a*). Set light to the wood and bring it into the cylinder. Does the wood burn differently in the "active air"? What kind of product does it appear to form? Compare this with the product which you concluded was formed by burning wood in air.

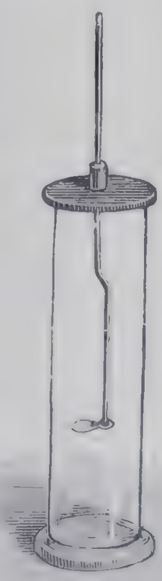

FIG. 60. — Deflagrating spoon in gas cylinder.

(*c*) Burn a piece of sulphur in a cylinder full of "active air," placing the sulphur in a deflagrating spoon. What kind of product appears to be formed? Smell the contents of the jar. Pour a little water into the jar and shake it with the gas. Add a drop or two of litmus solution to the water. Describe the effect produced on the litmus. What do you learn from this result about the solution?

(*d*) Burn another piece of sulphur in a jar containing air. Examine the contents of the jar. Has the product formed the same effect on litmus?

(*e*) Place a tiny fragment of charcoal in a deflagrating spoon and burn it in a cylinder of "active air." Pour a few c.c. of water into the jar and shake with the gas. Find what effect this solution has on the colour of litmus.

(*f*) Obtain the tube used in Exercise 67 (*f*). Dissolve the product obtained from burning phosphorus by pouring distilled water through the tube. Find what effect the solution has on litmus.

From the fact that acid products are formed when some substances burn in it, "active air" was called **oxygen** or "acid former." Substances, such as oxygen and sulphur, which cannot be split up into other simpler substances, are called **elements**.

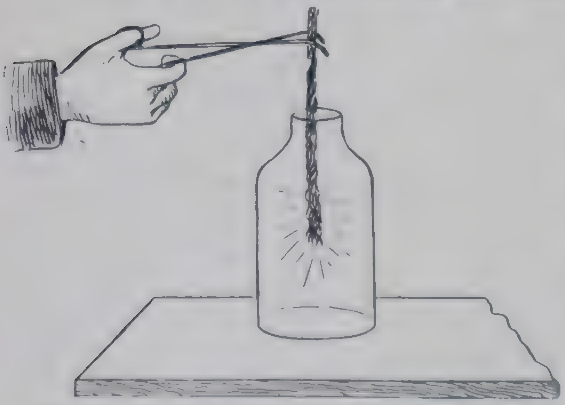

Fig. 61.—Iron wire burning in a jar of oxygen.

*(*g*) Twist together several pieces of thin iron wire so that their ends form a kind of brush (Fig. 61). Attach a small piece of cotton wool to the ends. Set the wool on fire and hold the iron inside a jar full of oxygen. Describe what you see happen, and examine the product formed.

The products formed when elements such as iron, phosphorus, sulphur and magnesium combine with oxygen, are called **oxides**. Pure substances, which like oxides are made up of two or more elements, are termed **compounds**.

ADDITIONAL EXERCISES. XII.

1. Find the loss of weight which sulphur undergoes when heated in air. Calculate the change in weight as a percentage of the amount originally taken. What evidence have you as to the cause of the loss in weight?

2. Heat in a small tube as much sulphur as will go on a knife blade. Note carefully the changes which occur to the sulphur.

3. Heat a weighed quantity of sugar in a crucible. Observe what happens to the sugar when heated. Find the change in weight and calculate this as a percentage of the weight of sugar taken. Examine the product left after the heating of the sugar. What substance does it resemble?

4 Examine the red oxide formed by roasting mercury in air. Weigh out as much as will go on a sixpence into a previously weighed test tube. Heat it slowly in a Bunsen flame, turning round the tube while doing so. Allow it to cool once. Then heat more strongly. Find what you can about the products of the change which occurs, and ascertain what change of weight there is.

5. Weigh some granulated zinc into a crucible. Heat it with a blowpipe flame. Have the crucible lid ready to be put on when the zinc begins to burn. Regulate the heating so as to lose as little as possible of the product formed by the burning. Find the percentage change in weight. Then examine the product with the object of finding whether "active air" can be obtained from it.

6. Find the percentage loss in weight when potassium chlorate is heated alone in a hard glass tube.

7. Discover whether oxygen can be prepared by heating pyrolusite alone.

CHAPTER XIII.

ACIDS AND METALS.

73. The Action of Zinc on Oil of Vitriol.

(*a*) Refer to your notes on Exercise 52 (*h*). What takes place when oil of vitriol is poured over zinc?

Prepare the apparatus described below (Fig. 62) in order to collect the gas formed from the action of the zinc on acid. Provide a flask holding about 500 c.c. with a cork which fits it tightly, a thistle funnel, and a delivery tube bent as described in Exercise 31 (*c*) so that the gas may be collected over water in a pneumatic trough (Fig. 21). Place the lower end of the tube in the water. In order to test the apparatus for leakage, warm the flask by clasping it in your hands, and notice whether the bubbles of air leave the

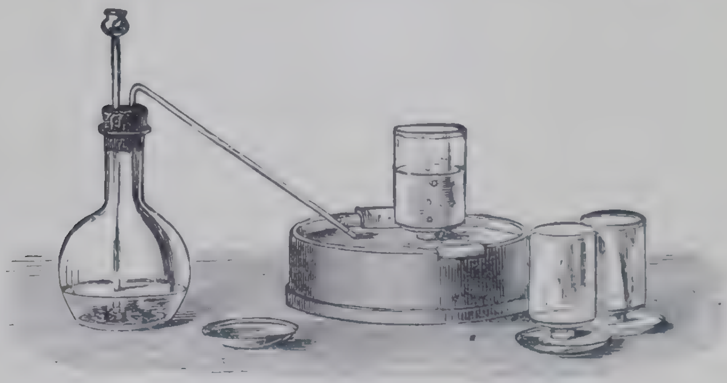

FIG. 62.—Collecting the gas formed from zinc and oil of vitriol.

tube regularly. If they do not, the defect must be remedied before you proceed with the experiment. Collect the gas at first in test tubes filled with water and placed mouth downwards in the trough, as shown in Fig. 62.

(*b*) Weigh 25 grams of zinc on the rough laboratory balance and place them in the flask. Pour 100 c.c. of dilute oil of vitriol, prepared as in Exercise 52 (*c*), through the thistle funnel. Collect the gas formed. Allow the first three tubes of gas to escape. Take the next from the water, closing its mouth with your thumb before you do so. Keep its mouth downwards. Obtain a lighted taper. Remove your thumb and thrust the lighted taper some way into the tube. Withdraw the taper again slowly. Notice exactly what happens. If the gas burns with explosion, allow the next tube collected to escape. When a tubeful of the gas burns quietly, you may consider it free from air. Why is this? Write out briefly the chief properties of the gas as you now know them.

(*c*) When gas ceases to be given off from the mixture in the flask, filter the liquid remaining into a basin and boil it till its bulk is reduced to about two thirds. Then set it aside until you are again working in the laboratory. If after the lapse of that time any crystals have formed, free them from the liquid by filtration. Examine them. Pick out the most perfect ones, dry them between absorbent paper, and keep them in a small tube bearing a label with the names of the substances from which the crystals were prepared. If no crystals have formed, reduce the bulk of the solution by boiling, until crystals form in it, when it is left to cool.

74. The Action of Iron on Oil of Vitriol

(*a*) Place a small piece of cast iron in a test tube. Pour over it a little dilute oil of vitriol. Describe as well as you can what takes place.

(*b*) Obtain the apparatus used in Exercise 73 (*a*). Place in the flask 10 grams of broken cast iron. Pour over it 100 c.c. of dilute oil of vitriol. Apply heat, if necessary, to start the action. Collect some of the gas and ascertain if it is similar to the gas collected in Exercise 73 (*b*). Keep the contents of the flask for use in the next exercise.

(*c*) Filter the liquid left in the flask into a basin. Boil half of it away. Set it aside for a day at least. Separate the crystals that have formed from the liquid. Dry them and compare them with those obtained from zinc and oil of vitriol. Keep a few of the more perfect in a labelled test tube. In the event of crystals not having formed, boil away some more of the liquid and let it stand again.

*75. The Action of Zinc on Acetic Acid.

(*a*) Pour a small quantity of diluted acetic acid over a piece of granulated zinc in a test tube. If no results are apparent, warm the mixture. Describe what takes place.

(*b*) Collect the gas formed in this case over water, as you have done previously, but arrange the apparatus so that the flask can be heated. Place a piece of wire gauze or an asbestos mat between burner and flask. Use 5 grams of zinc and 20 c.c. of strong acid, diluted with 20 c.c. of water. Procure a sample of gas which will burn quietly.

(*c*) Boil the acid until all the zinc has been dissolved. If more acid is needed, dilute a further quantity, and add a few c.c. at a time. Filter the liquid and evaporate it until crystals form in it. Free the crystals from liquid by filtration. Dry them between absorbent paper. Keep a specimen of them in a corked and labelled tube.

76. The Action of Magnesium on Acetic Acid

(*a*) Weigh 1 gram of magnesium ribbon and cut it into small pieces. Mix in a boiling tube 10 c.c. of strong acetic acid and 20 c.c. of water. Drop in the magnesium a few pieces at a time. While the gas is being given off rapidly, hold a lighted taper at the mouth of the tube. When have you seen a similar phenomenon?

(*b*) If the acid is not sufficient to dissolve all the magnesium, mix a further quantity in the same proportion and add it to the mixture already in the tube, a few c.c. only at a time, until the metal is dissolved.

(*c*) When the magnesium is dissolved, filter the solution, boil a third of it away, and allow the remainder to stand. If necessary reduce its bulk still further by boiling, until crystals are formed. Preserve some of the crystals.

*77. The Action of Iron on Muriatic Acid.

(*a*) Examine the action of muriatic acid on iron. For this purpose use the apparatus described in Exercise 73 (*a*). Place in the flask 15 grams of pieces of cast iron. Pour over them 15 c.c. of strong muriatic acid previously diluted with three times its volume of water. Apply heat, if necessary, to start the action. Collect a tube of the gas free from air.

(*b*) Prepare crystals by boiling down the liquid from the preceding exercise over steam and allowing it to stand. Preserve a specimen of the crystals.

*78. The Action of Zinc on Muriatic Acid.

(*a*) Study this action on a small scale, using one piece of granulated zinc and a small quantity of acid diluted with three times its own volume of water.

(*b*) Procure the apparatus used in Ex. 73 (*a*). Place in it 5 grams of granulated zinc. Mix in a beaker 20 c.c. of strong muriatic acid and 60 c.c. of water. Pour this down the thistle funnel and collect the gas evolved, as you did in

Exercises 73 (*b*) and 74 (*b*). When you have collected a tube of the gas which will burn without explosion, allow the action to complete itself, but do not trouble to collect more of the gas.

(*c*) When the evolution of gas has ceased, filter the liquid and evaporate it in a basin to less than half its volume. Then place it on a water bath and evaporate it to dryness. Examine the substance that remains and compare it with those formed in Exercises 73 (*c*) and 74 (*c*). Keep a specimen of this substance in a corked tube.

79. A Comparison of the Action of Various Acids on Metals.

(*a*) Collect into a table the knowledge you have now gained as to the action of acids on metals:

ACID.	EFFECT ON METAL.	SUBSTANCE FORMED IN SOLUTION.	KIND OF GAS PRODUCED.
Oil of Vitriol	Iron		
" "	Zinc		
Muriatic Acid	Iron		
" "	Zinc		
Acetic Acid	Magnesium		
" "	Zinc		

(*b*) After studying the table, write down the points where you consider that the actions of these acids on the same metal are similar and dissimilar. In what respects do all three acids have similar effects when they act on the metals to which you have given your attention?

(*c*) Write an account of the gas which is formed in all the cases in which you have studied the action of an acid on metal.

On account of its power of burning in air this gas was called "inflammable air" by its discoverer, Cavendish.

(*d*) Discover whether "inflammable air" is formed when magnesium acts on dilute muriatic acid.

ADDITIONAL EXERCISES. XIII.

1. Study and write a careful account of the action of nitric acid on magnesium.

2. Compare the products formed when nitric acid acts on iron with those usually formed when acids act on metals.

3. Find whether tin and lead are soluble in muriatic acid under any conditions.

4. What is the effect, if any, of putting copper into (i) dilute nitric acid, (ii) dilute oil of vitriol? Is any different effect produced when the mixture is warmed?

5. Find out all you can about the action of muriatic acid on aluminium and on lead.

6. What is the action of the various acids on the metal of which a penny is made? Does this give you any clue as to the metals present in a penny?

CHAPTER XIV.

INFLAMMABLE AIR AND THE COMPOSITION OF WATER.

80. The Preparation in Quantity of "Inflammable Air."

(*a*) Procure a large wide-mouthed bottle and a large flask with well fitting rubber stoppers through which pass in each case two tubes (Fig. 63). The longer tube must reach the bottom of the bottle and flask respectively. Connect the flask and bottle as shown in Fig. 63 with a rubber tube two feet long. Place a clip on the short tube of the bottle.

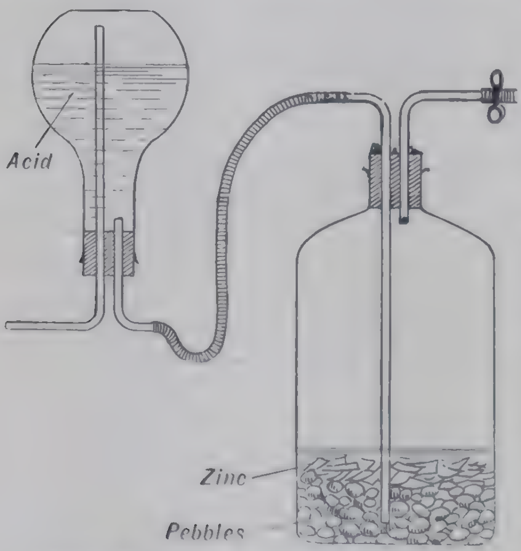

Fig. 63. The preparation in quantity of "inflammable air."

Obtain some clean pebbles. Place a layer of pebbles in the bottle sufficient to cover completely the end of the long tube. On the pebbles put a layer of zinc.

For this exercise it is best to use zinc which has been melted and poured into a shallow vessel to cool. The sheet thus formed must be broken with a hammer into pieces small enough to enter the bottle.

(*b*) Dilute a quantity of oil of vitriol by pouring it gradually into eight times its own volume of water. Cool the mixture and three parts fill the flask with it. Replace the stopper. Invert the flask quickly and clamp it in that position (Fig. 63). Open the clip which closes the short tube in the bottle, and thus allow air to escape and acid from the flask to take its place. When it is desired to stop the current of gas, close the clip, so that the acid is forced back into the flask.

81. The Properties of "Inflammable Air."

(*a*) Procure a delivery tube bent like that described in Exercise 49 (*f*), (Fig. 37). Attach this to the bottle in which the "inflammable air" is prepared. Open the clip and collect the gas in inverted test tubes over water. As each tube of gas is collected find if it burns quietly without explosion. As soon as the gas burns quietly in the tube, collect it in gas cylinders as it is needed in the experiments described hereafter.

(*b*) From an examination of the gas thus collected, ascertain its smell, taste, and colour.

(*c*) Leave a cylinder of the gas mouth upwards on the bench without its cover. After waiting a minute plunge a lighted taper into the jar. From what you observe, decide what must have happened to the gas. Repeat this holding the jar *mouth downwards*. Note exactly any difference.

"Inflammable air" is so light that it is difficult to determine its density accurately. The most careful experiments have shown that 1 litre of the gas weighs 0·09 gram.

*(*d*) In a similar manner to that described in Exercise 64 (*e*) measure the amount of "inflammable air" which

dissolves in 100 c.c. of water at atmospheric temperature and pressure.

(*e*) In place of the delivery tube, attach to the bottle a jet made from a broken clay-pipe stem. Place a test tube over the jet as far as it will go. After a minute or two close the mouth of the test tube with your thumb and bring it to a gas flame, *which must be a few feet away from the jet.* The gas may at first go off with a pop, or burn with a squeaking noise, but after two or three trials it will burn quietly, with a blue flame. *When you can carry this flame of burning "inflammable air" to the apparatus from which the gas is being produced, do so, and use it to ignite the gas escaping from the jet.* If you remember always to do this, there can be no danger, for when you can carry the flame in a test tube of the gas for a distance of two or three feet, you may be sure that the gas which fills the apparatus is not explosive.

Describe the appearance of the flame. Hold over it a cool and dry glass jar. Examine the inside of the jar and find what effect is produced.

(*f*) Draw up a table similar to that prepared in Exercise 64 (*f*), and thus compare the principal properties of "inflammable air" with those of "active" and "inactive air." After filling in the table, decide the main points in which "inflammable air" differs from the other two gases.

82. The Product obtained in the Burning of "Inflammable Air."

(*a*) Examine more carefully the product formed in Exercise 81 (*f*). For this purpose collect a small quantity of it by placing over the flame a clean surface kept constantly cool.

To ensure that the "inflammable air" is perfectly dry before it is burnt, pass the gas, as it leaves the bottle in which it is made, through a bottle containing fragments of glass moistened with strong oil of vitriol (Fig. 64, *a*).

> Oil of vitriol has the power of absorbing water; it is therefore constantly used to dry gases.

The tube through which the gas enters must reach to the bottom of the drying bottle. The second tube may be quite short. See that the rubber stopper fits tightly.

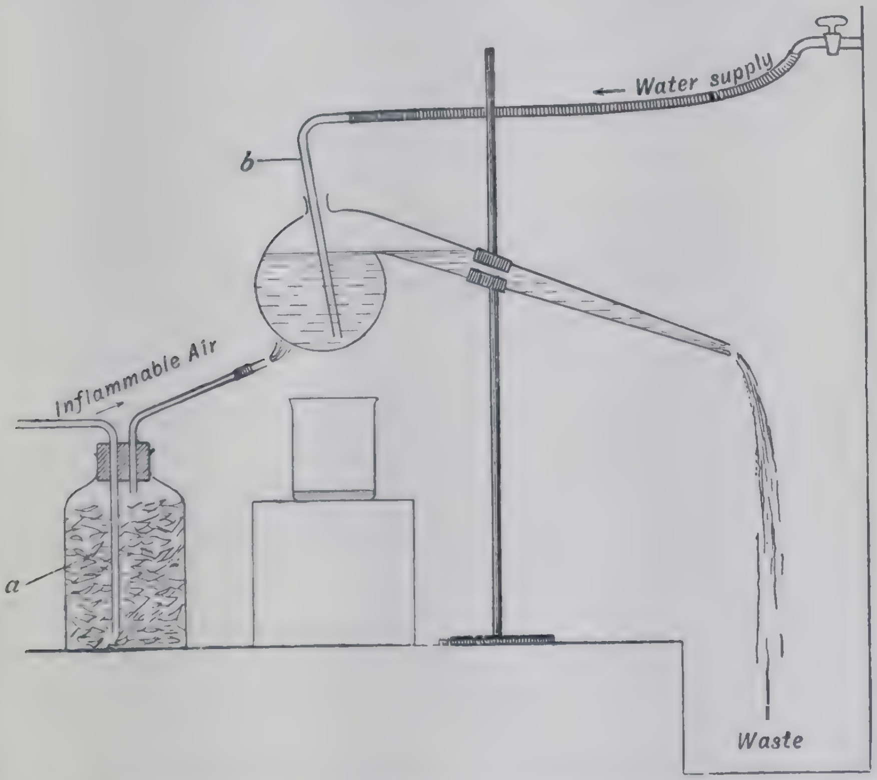

FIG. 64.—Collecting the product obtained in the burning of "inflammable air."

(*b*) Procure a retort and remove the stopper. In place of the stopper fix a cork holding a glass tube which reaches to the opposite side of the retort (Fig. 64, *b*). Connect this tube with the water supply. By means of a retort stand, fix the retort immediately above the jet, so that the flame of "inflammable air" when lighted shall play on the part of the retort cooled inside by the current of water (Fig. 64).

Light the gas at the jet *as directed in Exercise* 81 (*f*). Observe what is formed on the retort. Place a clean vessel on the bench beneath the retort so that the drops of liquid formed fall into it.

(*c*) When about 2 c.c. of the liquid has been collected, proceed to examine its properties. Remove a drop on the end of a clean glass rod and taste it. Has the liquid any taste or smell? Find first the freezing point, then the boiling point of the liquid in the manner described in Exercises 33 (*c*) and 34 (*a*). What liquid that you know has properties similar to these? Draw up a table containing side by side the properties of the liquid you have just prepared and those of the liquid you suspect it to be. Decide what the new liquid must be.

83. Proof of the Composition of Water.

(*a*) From the knowledge you have already gained that a substance, when burning in air, is combining with the oxygen of the air, decide of what water is composed.

*(*b*) In order to test the truth of the theory that water is a compound of "inflammable air" and oxygen, pass "inflammable air" over some substance which when heated gives up its oxygen. Write a list of the substances which you think might be used for this purpose.

> Of the substances which you have already examined, red lead serves the present purpose best.

Obtain a piece of hard glass tubing 20 cm. long and 1·5 cm. in external diameter. Heat this near the end in the blowpipe flame and draw it out into a tube of about a fifth the diameter. When the narrower part of the tube is cool, bend it at right angles near the constriction, so that the final result is as shown in Fig. 65. For the wider end of this tube procure a tightly fitting rubber stopper through which passes a short connecting tube. Procure the apparatus used in Exercise 80 for the preparation of "inflammable air."

In order to know at what rate the "inflammable air" is leaving the bottle, pass it through a wash bottle. For this purpose, fit a small wide-mouthed bottle with a rubber stopper and two tubes, one long and one short. Place in the bottle sufficient oil of vitriol to cover the end of the longer tube (Fig. 66, *a*). To the shorter tube connect the drying bottle containing broken glass, so that the gas may pass through this also (Fig. 65, *a*).

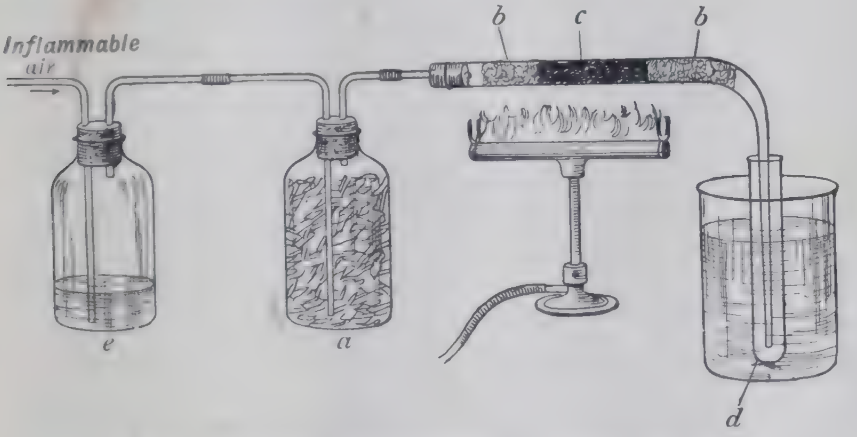

FIG. 65.—Passing "inflammable air" over heated red lead.

Make an asbestos plug (Fig. 65, *bb*) to fit each end of the hard glass tube. Pack the tube between these plugs with red lead (Fig. 65, *c*) as tightly as is consistent with the passage of gas through the tube. Fit together the whole apparatus as shown in Fig. 65. When this has been done, test for possible leakage by attaching a delivery tube to the end of the hard glass tube and thus passing the gas through water. Compare the rate at which bubbles pass out with the rate at which they pass through the wash bottle. If there is a leak, each part of the apparatus must be tested separately until the defect is discovered. Collect the gas which has passed through the apparatus in tubes over water. Bring each tube of gas to a flame as you did in Exercise 81 (*f*) until the gas burns quietly without explosion. When the apparatus is thus shown to be free from air, remove the delivery tube and place the bent end of the hard glass tube as far as it will go into a test tube (Fig. 65, *d*). Cool the outside of this test tube by placing it in a vessel full of water.

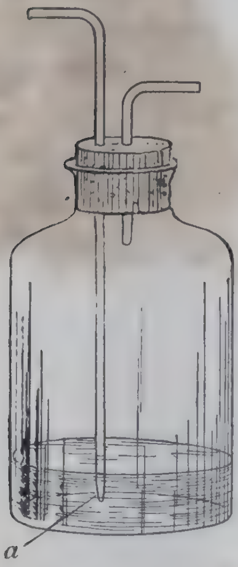

FIG. 66.—Wash bottle.

To heat the tube containing the red lead, procure a long burner so that as much as possible of the tube may be heated at once (Fig. 65). If such a burner is not available, use a circular Fletcher burner. Warm the tube gradually at first, moving the flame constantly so that no part may be heated more than the rest. Gradually turn on the gas until the full flame is being used. What change in appearance do you observe in the lead? At the close of the experiment drive as much as possible of the liquid which is formed into the test tube, by heating the narrower parts of the tube. Remove the end of the tube from the test tube before taking away the flame.

> A process such as has now been carried on, where a substance is forced to combine with oxygen, is called an **oxidation**. The substance which supplies the oxygen is called the **oxidizing agent**.

*(*c*) Fit the test tube containing the liquid with a thermometer as in Exercise 33 (*c*), and take the freezing point and boiling point of the liquid. What proof have you that the liquid is water?

(*d*) Write down exactly how this experiment proves that water is a compound of "inflammable air" and oxygen.

The name **hydrogen** was given to the gas which has been up to this point called "inflammable air," to express the fact that it was one of the two elements which take part in the formation of water. The name, taken from two Greek words, means "water former."

*84. Hydrogen obtained from Water.

(*a*) Obtain a hard glass tube about 20 cm. long. Connect tubes to it as shown in Fig. 67 by means of tightly fitting corks. Pack the middle of the tube with iron nails or tacks.

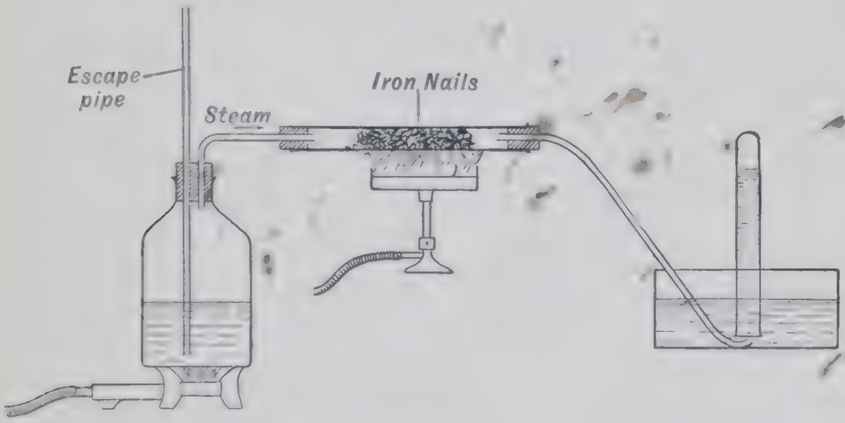

Fig. 67.—Passing steam over heated iron.

Pass steam through the tube from a tin can or large flask. Provide the can or flask with a glass tube, about half a metre long, open at both ends, arranged to pass below the surface of the water in the can. This acts as an escape valve (Fig. 67).

While the steam is passing quickly through the glass tube, heat the nails as strongly as possible. Collect over water the gas which issues from the tube. Does it consist of something besides steam? Collect sufficient of this gas to identify it.

Allow the tube to cool. Examine the iron and observe how it has changed. Compare the substance which has collected on the iron with that formed when iron was burnt in Exercise 72 (*g*). What does the iron seem to have taken from the water?

> A substance which can remove oxygen from another substance, as the iron does from the water in the preceding exercise, is called a **reducing agent.** The process is termed **reduction.** It is the exact opposite of the process of "oxidation," mentioned in Exercise 83 (*b*).

85. The Volume of Hydrogen obtained by the use of a known Weight of Metal.

(*a*) Fit a Winchester quart bottle with a sound rubber stopper which has two holes. Fit one hole with a short tube bent at right angles (Fig. 68, *a*). Through the other hole pass a second tube (Fig. 68, *b*) bent once at right angles above the stopper, but passing to the bottom of the bottle. To the free end of the shorter tube connect a small flask (Fig. 68, *c*) holding about 100 c.c. Connect the longer tube with a delivery tube (Fig. 68, *d*) by means of a rubber connection. On the latter place a clip. Fill three quarters of the bottle with water. Open the clip. Remove the small flask from the shorter tube and blow through that tube until the delivery tube is full of water. Close the clip so that the delivery

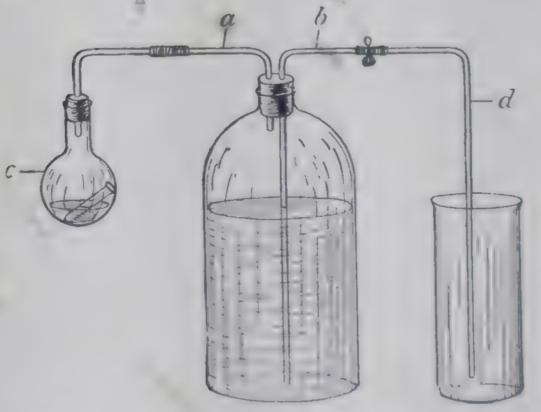

Fig. 68.—Measuring the volume of hydrogen obtained by using a known weight of zinc.

tube remains full of water. Place the end of the delivery tube in a dry measuring cylinder.

Weigh accurately about 0·5 gram of granulated zinc in a small piece of tissue paper. Place the zinc wrapped in the paper at the end of a test tube small enough to enter the flask. Pour into the flask about 50 c.c. of dilute oil of vitriol. Hang the test tube containing the zinc in the flask by means of a thread so that the acid cannot enter the tube. When all is ready drop the tube into the acid and immediately connect the flask to the rest of the apparatus, and open the clip.

When the zinc has been dissolved entirely, allow the flask to cool, hold the cylinder so that the surface of the water which has been driven into it is level with the surface of the water in the bottle, and close the clip. Measure the volume of water in the cylinder. What does this volume exactly represent? Calculate the volume of gas obtained from 1 gram of zinc as follows:

Volume of hydrogen set free by ... gram of zinc = ... c.c.
∴ volume of hydrogen set free by 1 gram of zinc = ... c.c.

Note the height of the barometer and the temperature of the air in the room. Calculate what the volume of gas would be at 0° C. and 760 mm. (Exercises 59 and 61). Compare your result with those of the other students, if this is possible. If you cannot do this, repeat the work till you obtain two results which agree together.

(*b*) Procure some dilute muriatic acid and find the volume of hydrogen evolved by its action with one gram of zinc. Proceed as with oil of vitriol.

(*c*) Repeat Exercises 85 (*a*) and (*b*), but using either (i) iron wire, or (ii) magnesium ribbon, in place of the zinc. Use not more than 0·4 gram of iron and 0·2 gram of magnesium. Calculate in a similar way the volume of the gas at 0° C. and 760 mm., obtained by the use of one of these metals.

(*d*) Collect the results into a table:

ACID.	METAL.	VOLUME OF GAS, USING 1 GRAM OF METAL.	
Oil of vitriol	Zinc	Expt. 1 …… c.c.	Average …… c.c.
” ”	”	” 2 …… c.c.	
” ”	Iron	Expt. 1 …… c.c.	Average …… c.c.
” ”	”	” 2 …… c.c.	
” ”	Magnesium	Expt. 1 …… c.c.	Average …… c.c.
” ”	”	” 2 …… c.c.	
Muriatic Acid	Zinc	Expt. 1 …… c.c.	Average …… c.c.
”	”	” 2 …… c.c.	
”	Iron	Expt. 1 …… c.c.	Average …… c.c.
”	”	” 2 …… c.c.	
”	Magnesium	Expt. 1 …… c.c.	Average …… c.c.
”	”	” 2 …… c.c.	

(*e*) By the aid of this table compare the volume of gas obtained from either acid by using 1 gram of zinc. Similarly compare the amounts obtained by using one gram of iron and one gram of magnesium. What conclusion do you draw from these results?

ADDITIONAL EXERCISES. XIV.

1. Prepare a “zinc-copper couple” by letting 25 grams of granulated zinc stand in blue vitriol (copper sulphate) solution for an hour. Place the “couple” in a flask full of water, boil the water, and collect the gas which is formed over water. Examine the gas and find what it is.

2. Discover whether hydrogen will burn in nitrogen.

3. Pass steam over magnesium ribbon heated in a hard glass tube, and discover what are the products of the action.

4. Find out all you can of the action of steam on highly heated zinc.

CHAPTER XV.

A STUDY OF CHALK AND LIMESTONE.

86. Limestone and Lime.

(*a*) Refer to your notes on Exercise 48, and by their aid write an account of the properties of chalk, limestone, and marble. What effects have acids on the three substances?

*(*b*) Determine carefully the weight of powdered limestone, chalk, or marble, which dissolves in 100 grams of water at the temperature of the room.

(*c*) Procure some freshly burnt lime. Examine and describe it. Place a lump in a basin and pour on it *one* or *two drops* of water. Leave the lump for a few minutes. If nothing seems to take place add one or two drops more water. When the lump has crumbled, compare the "slaked lime" with the fresh.

> Lime which has been mixed with water is said to be "slaked."

(*d*) Write what you know of the properties and uses of lime. What precaution must be taken in storing it?

*(*e*) Find what weight of slaked lime will dissolve in 100 grams of water at atmospheric temperature. How does the solubility of lime compare with that of chalk?

(*f*) Make a paste by stirring some lime with a few drops of water. Find what effect this paste has when rubbed on blue and red litmus paper. Discover whether a paste made of powdered chalk, marble, or limestone has a similar effect on the colour of litmus.

(*g*) Weigh some lime and chalk in separate watch glasses. Leave them in the air for some time and see whether either powder changes in weight.

87. The Preparation of Lime from Chalk.

(*a*) Write what you know of the manufacture of lime. Describe the process used.

(*b*) In order to see if you can get lime from chalk, weigh a small quantity—not more than 1 gram—of chalk into a previously weighed crucible. Heat it for some time over a Fletcher burner. Let it cool and weigh it again.

Record the results of your weighings in the manner shown below.

Weight of crucible and chalk - - - = ... grams
Weight of crucible alone - - - = ... grams
∴ weight of chalk taken - - - = ... grams

Weight of crucible and chalk before being heated = ... grams
Weight of crucible and chalk after being heated = ... grams
∴ loss in weight of chalk - - - = ... grams

Loss in weight of ...... grams of chalk - = ... grams
∴ loss in weight of 100 grams of chalk = ... grams

Preserve the substance in the crucible for use in the following exercise.

(*c*) Examine the substance in the crucible. To one portion add a few drops of water. Is any effect produced like the slaking of lime? Make a paste with another portion, as in Exercise 86 (*f*). Does this paste produce any effect on litmus paper? Do you consider the substance in the crucible to be lime, or chalk, or a mixture?

* (*d*) Procure a small piece of platinum foil and bend up

its edges. Find its weight, first alone, then containing a small quantity of powdered chalk or marble. Heat the chalk as fully as possible over a Fletcher burner, taking care to spill none. Let it cool and then weigh it again. What change of weight is there? As in Exercise 87 (*b*) calculate this change as a percentage of the weight of chalk taken. Write out the results in a similar way. Leave the powder in the air for a few minutes, and notice whether any further change of weight occurs. Next examine it and ascertain whether there is much lime present.

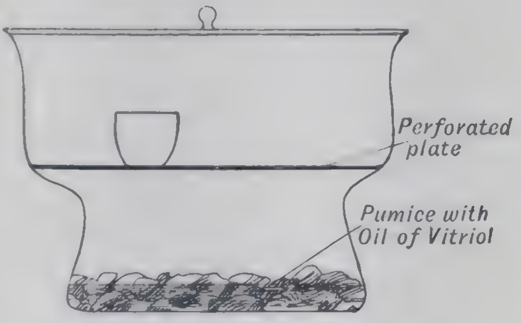

FIG. 69.—Desiccator ready for use.

(*e*) Prepare a desiccator (Fig. 69), for use. Place a number of lumps of pumice in the lower part and pour over them a layer of strong oil of vitriol half an inch deep. Replace the perforated plate. Grease the top slightly with lard, so that the lid fits air-tight.

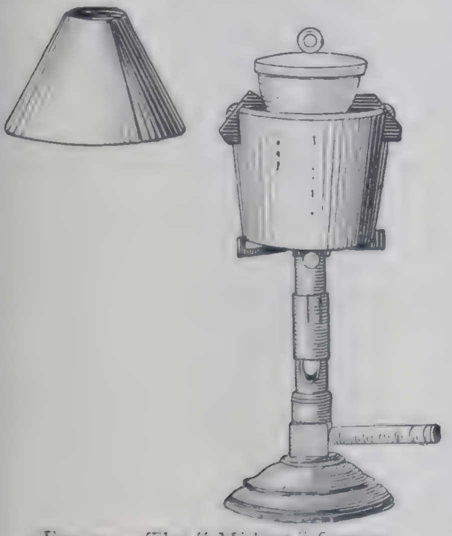

FIG. 70.—The "Midget" furnace.

In the following exercises use a more delicate balance than you have done up to this point.

For the following exercise a muffle furnace is needed. Where a muffle furnace is not available, the "Midget" furnace[1] may be used instead (Fig. 70). This consists of two truncated cones of sheet iron, lined with asbestos. The lower portion must be fixed over the mouth of a burner (preferably the special burner supplied for use with the furnace). The vessel to be heated must be placed on the three iron arms inside the lower portion and then covered with the upper portion.

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[1] The "Midget" furnace is supplied by Messrs. Brewster, Smith & Co., as are also the special burners for use with the furnace.

(*f*) Take again the small crucible used in Exercise 87 (*b*). Heat it over a Bunsen flame till it is red hot. Lift it from the flame with the crucible tongs and place it in the desiccator to cool. Find its weight alone. Then weigh into it rather less than a gram of powdered chalk or marble. Enter your weights in the following manner:

Weight of crucible and chalk - - = ... grams
Weight of crucible alone - - - = ... grams
∴ weight of chalk - - - - = ... grams

Heat the crucible for at least three-quarters of an hour in a muffle furnace which is working well. Then place the crucible in the desiccator. When the crucible is cool weigh it again. Find if there has been any change of weight, and record your results in a similar way to the example given in Exercise 87 (*b*).

Replace the crucible in the furnace and heat again for another half hour. Again allow it to cool in the desiccator, and find if its weight has again altered. If there has been any further change, repeat the heating and weighing until on two successive occasions its weight is the same.

The crucible containing the chalk must be kept in the desiccator during the whole of this work, except when it is actually being heated or weighed.

Find the final change in weight of the chalk. Express this result as a percentage of the weight taken, in the following way:

Weight of crucible and chalk before being heated - - - - - = ... grams
Weight of crucible and chalk after the final heating - - - - = ... grams
∴ loss in weight of chalk - - = ... grams

∴ loss in weight of ...... grams of chalk = ... grams
∴ loss in weight of 100 grams of chalk = ... grams

Finally, determine whether the contents of the crucible are chalk or lime.

(*g*) Compare the loss in weight of the chalk found in the three Exercises 87 (*b*), (*d*) and (*f*). To what cause do you attribute the differences in these three results? What do you consider the loss in weight caused by the *total conversion* of limestone to lime?

88. The Action of Acids on Chalk.

(*a*) Refer to your notes on Chapter IX., and with their aid write an account of the action of the four acids—oil of vitriol, muriatic acid, nitric acid, and acetic acid—on chalk and on powdered marble.

(*b*) In order to find if any change of weight occurs when acids act on powdered chalk or marble, and what volume of gas is formed, arrange the following apparatus. Obtain a flask holding about 100 c.c., and choose a test tube 6 cm. long and narrow enough to pass easily through the mouth of the flask. Fit the flask with a rubber stopper pierced with two holes. Through each hole pass a small tube, bent at

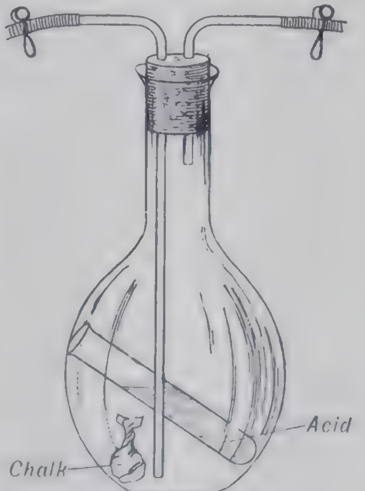

FIG. 71.—Small flask for use in Exercise 88 (*b*).

right angles just above the stopper, and reaching in one case just through the stopper, in the other to the bottom of the flask (Fig. 71).

Fit a Winchester quart bottle with a rubber stopper, through which pass two glass tubes, bent at right angles above the stopper (Fig. 68), and reaching one to the bottom, the other just through the stopper. To the former connect a right angled delivery tube reaching to the bench (Fig. 68 *d*). Fill the bottle with water so far that the shorter tube is just clear of the water. Fill the delivery tube with water. Place the delivery tube in a dry measuring cylinder.

Weigh about 0·7 gram of chalk, or powdered marble, on a piece of fine tissue paper. Rice paper is best for the purpose. Screw up the chalk in the paper and drop it into the flask. Fill the test tube three-quarters full of muriatic acid and lower it into the flask by a piece of cotton, taking great care that none of the acid is spilt from the tube. Weigh flask and contents, and then connect the shorter tube in the flask with the shorter tube in the bottle. Close the second tube in the flask with a clip. Tilt the test tube so that the acid reaches the chalk. Continue this until the chalk is wholly dissolved. When the gas begins to come off more slowly, keep the end of the delivery tube *below the surface* of the water collected in the measuring cylinder. In this way keep the water in the delivery tube unbroken by air bubbles.

When no more gas is evolved, warm the liquid in the flask slightly and then leave the apparatus to cool. Note the volume of water expelled. Remove the small flask and drive a current of air gently through the longer tube in order to expel from the flask the gas it contains and replace it with air. Weigh the flask and its contents again, and find what loss of weight there is. Record your result as follows:

Weight of flask and contents at first - = ... grams
Weight of flask and contents after the loss of gas - - - - - = ... grams
∴ loss in weight of chalk - - = ... grams
Loss in weight of ...... grams of chalk - = ... grams
∴ loss in weight of 100 grams of chalk = ... grams

*(*c*) The volume of gas evolved being known from the volume of water expelled, and its weight from the loss in weight of the flask, calculate the weight of one litre of the gas as follows:

Loss in weight of flask - - - = ... grams
Volume of gas evolved - - - = ... c.c.
∴ ...... c.c. of gas weigh ...... grams
∴ 1000 c.c. of gas weigh ...... grams

Compare this result with those of your fellow-students. If it differs markedly from the average, repeat the work. If you cannot compare your own with other results, obtain yourself two results which agree with one another.

*(*d*) Repeat the exercise, using first strong nitric acid and then oil of vitriol diluted with its own volume of water, instead of muriatic acid.

(*e*) Tabulate the results you obtain thus:

ACID USED.	WEIGHT OF CHALK TAKEN.	LOSS OF WEIGHT.	LOSS PER CENT.	VOLUME OF GAS MEASURED.	WEIGHT OF ONE LITRE OF GAS.
Muriatic					
Nitric					
Oil of Vitriol					

From these numbers work out the average loss in weight of 100 grams of chalk, and the average weight of a litre of the gas formed from the chalk.

89. The Preparation in Quantity of the "Chalk Gas"

Until more is learnt of its composition, the gas prepared from chalk and acids will be known as "Chalk Gas."

(*a*) Procure an apparatus exactly similar to that used in Exercise 80, for the preparation of hydrogen in quantity. On the layer of pebbles place a number of lumps of marble. Dilute a quantity of muriatic acid with its own volume of water and half fill the empty flask with it. Raise the flask until the acid covers the marble. When the acid has frothed up almost to the top of the bottle, and has therefore driven out the air, close the clip on the delivery tube until the gas is needed.

90. The Composition of Chalk.

(*a*) Compare the average loss in weight per cent. found in Exercise 88, with the percentage loss when chalk is heated in the furnace [Exercise 87 (*f*)]. What conclusion can you draw from the similarity of these numbers as to the cause of chalk losing weight when heated? May not both changes be due to the loss of "chalk gas" by the chalk? What then must be the two substances of which chalk is composed?

(*b*) Pour into a test tube a little clear lime water and add an equal quantity of distilled water. Pass through the liquid some of the gas prepared by the action of acid on chalk. What takes place in the clear solution? Continue to pass the gas for several minutes after the first change is observed in the liquid. What further change takes place?

(*c*) In order to collect the solid formed by the action of "chalk gas" on lime water, prepare a large bottle full of clear lime water and pass the gas through the liquid. If, in making the lime water, the lime takes too long to settle, filter the turbid solution.

At intervals, as the solid is being formed by passing the "chalk gas," filter a little of the liquid into a test tube. Pass the gas into this filtered solution and see if it causes a further *precipitate*.

> A solid formed in such a way as this from a clear solution is called a "precipitate."

When no further precipitate is caused by passing more gas, collect upon a large filter paper the solid which has been formed in the lime water. Wash it into the point of the cone with your wash bottle. Then fold the paper with the solid still on it, place it in a basin and dry it in a hot air oven. Make certain that the solid is perfectly dry.

(*d*) Remove a few particles of the solid from the filter paper. Place them in a test tube and pour over them a little dilute muriatic acid. Describe what takes place. What similar action have you seen?

* (*e*) Weigh into a small weighed crucible, previously heated and allowed to cool in a desiccator, about 0·7 gram of the solid from the filter paper. Heat it for an hour in the muffle furnace. Allow it to cool in a desiccator and weigh it again. Repeat the heating and weighing until its weight is constant. If there has been a loss of weight calculate what percentage this is of the weight of solid originally taken. Compare this with the loss in weight of chalk when heated [Exercise 87 (*f*)].

(*f*) From the results obtained in Exercises 90 (*d*) and (*e*) decide what the white solid formed in lime water is. What does this show chalk to be composed of? Compare this result with the conclusion you arrived at in Exercise 90 (*a*).

(*g*) In order to test the truth of your theory as to the composition of chalk, place some *freshly prepared*, slaked lime in a crucible at the bottom of a gas cylinder. Fill the cylinder with "chalk gas" and let it stand for some time. Stir the lime with a glass rod and pass a fresh supply of gas into the cylinder. Repeat this several times. Remove some of the solid into a test tube. Pour on it a few drops of dilute acid. What takes place? What solid seems to have been formed from the lime? Does this confirm the conclusion to which you have already come?

91. A Study of "Chalk Gas."

(*a*) Determine the density of "chalk gas" by the method used in Exercise 64 (*c*). Dry the gas before it enters the flask by passing it through a tube packed with cotton wool. Continue to pass through the flask until a few bubbles of it, collected over lime water, entirely dissolve. The flask may then be considered free from air. Compare the result with that obtained in Exercise 88 (*c*).

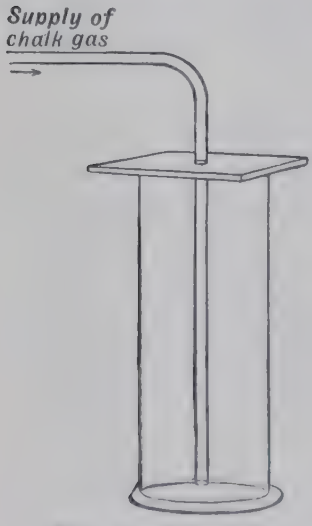

FIG. 72.—Collecting "chalk gas."

(*b*) Find the solubility of "chalk gas" in water by the method described in Exercise 64 (*e*). In measuring the gas driven from solution, collect it over water which has been previously saturated with the gas.

(*c*) Fill several cylinders with the "chalk gas," placing the delivery tube in the cylinder and covering the mouth of the cylinder with a piece of cardboard (Fig. 72). Has the gas any taste or smell?

(*d*) Taste water saturated with "chalk gas." Compare the taste with that of ordinary water. Of what does the taste of the solution remind you? Dip pieces of red and blue litmus paper into the solution. Notice what takes place after a minute or two. What conclusion must you reach as to the nature of the liquid formed by dissolving the gas in water?

(*e*) Hold a lighted taper at the mouth of a jar filled with the gas. Gradually lower it to the bottom and observe what happens. What means of ascertaining how much gas is contained in a jar does this result suggest?

Try if other burning substances will continue to burn in the gas.

(*f*) Lower a piece of burning magnesium ribbon into a jar of the gas. Examine carefully the substances formed. Compare the white solid formed, with the product formed when magnesium burns in air.

(*g*) Dip a small piece of cotton wool in turpentine. Place it in a basin and light it. Pour over the burning wool a large jar of "chalk gas." What effect has it?

> On account of its power of extinguishing burning substances, this gas is of great practical use. "Fire extinguishers" are charged with substances which can form "chalk gas."

(*h*) Write an account of the properties of the gas so far as you have discovered them.

(*i*) Draw up a table similar to that in Exercise 64 (*f*), comparing "chalk gas" with air, oxygen, and nitrogen.

92. "Chalk Gas" in Nature.

(*a*) Leave a shallow basin of clear lime water out in the air. What alteration is there in the lime water? Force air by means of bellows through clear lime water contained in a boiling tube and observe what takes place after a time. What do these two experiments suggest?

(*b*) Burn a few pieces of paper in a flask. After the burning has ceased, pour in a few drops of lime water and shake the flask. What effect is noticeable in the lime water?

(*c*) Blow air from your lungs for several minutes through clear lime water. For about the same time force air through another tube of lime water by means of the bellows. Compare the two tubes. What facts do you learn from this and the previous experiment? Can you now suggest any sources whence air may obtain a small amount of "chalk gas"?

(*d*) Fill a small flask with soda water or some other aërated water. Drive the gas from the liquid by means of heat and collect it. Lower a lighted taper into a jar of the gas. Apply other tests until you have decided what is the nature of the gas.

* (*e*) Procure some fragments of old mortar or plaster. Place a piece in a test-tube and pour over it some acid. What do you find happens? Decide what gas is evolved. Write down the materials of which the mortar was originally made, and then suggest how the chalk can have been formed in it.

93. The Hardness of Water.

(*a*) Pass "chalk gas" through lime water diluted with its own volume of water until the solution becomes perfectly clear. From the knowledge you have already gained, answer the following questions:

(i) What is the precipitate formed in the liquid?

(ii) How far is that solid soluble in water?

Finally try to suggest a reason for the solid dissolving in the liquid. When the liquid is clear, boil it and note what happens.

* (*b*) Examine the interior of a boiler, a boiler pipe, or a kettle, which has been used for some time for the boiling of water. If possible, obtain a fragment of the "fur" which has collected on the inside. Compare this "fur" with chalk or marble.

(*c*) Suggest a possible cause of the "furring" of kettles and boilers and for the hardness of water. Suggest also one method of removing the hardness of water.

ADDITIONAL EXERCISES. XV.

1. Find the loss in weight of eggshell when heated in the muffle furnace, as in Exercise 87 (*f*). Calculate the percentage loss in weight. What would you consider eggshell to be composed of? Perform other experiments to test the truth of what you suggest.

2. Collect the air dissolved in a quantity of tap water. Determine the percentage of chalk gas in this air, and compare it with the amount found to be present in ordinary air. Explain the difference in the proportion of "chalk gas" present.

3. Compare the properties of marble with those of the substance of which oyster or cockle-shells are formed.

4. Collect the gas which escapes from bottled beer or cider when heated, and decide what it is.

5. Devise and carry out an experiment by means of which you can show that chalk can be converted entirely into lime, and then restored to its original weight by means of chalk gas.

6. Perform experiments in order to determine the percentage of chalk in old mortar. Separate the other ingredients of the mortar as far as possible.

7. Allow a long tube containing a marked volume of air to stand in lime water for an hour. During that time shake the air with the lime water several times. What constituent of the air does the lime water absorb? At the end of the time what diminution of volume has taken place?

Decide whether the proportion of "chalk gas" present in air is large enough to be measured in this way.

CHAPTER XVI.

ALKALIES AND AMMONIA.

94. Soda or "Mild Alkali."

(*a*) Procure some crystals of washing soda. Sketch them in your notebook. Dissolve some washing soda in water and taste a drop of the solution. Rub a drop of the solution between finger and thumb. Does it feel in any way different from ordinary water?

(*b*) Make a saturated solution of washing soda. Find the number of grams of the solid dissolved in 100 c.c. of the solution.

* (*c*) Prepare a test tube with a tightly-fitting stopper and bent delivery tube, as shown in Fig. 35. Put an inch layer of soda crystals in the test tube and replace the cork. Slide another test tube over the end of the bent tube as far as it will go. Heat the soda with the flame of a Fletcher burner, at first very gently, in order to avoid cracking the glass. While the heating proceeds, keep the flame moving over the end of the tube so that no part of the tube is heated more than another. Keep the tube which acts as a collector cool, by putting it in a basin of water. After heating for a few minutes, what do you observe to have collected in the collecting tube?

* (*d*) In order to ascertain what the liquid you have collected in Exercise 94 (*c*) consists of, find the temperature

at which it boils and freezes. From the knowledge thus gained decide what the liquid is.

(*e*) Place a crystal of soda in a test tube and pour on it a few drops of dilute acid. Describe what takes place. What have you seen similar to this in your previous work?

(*f*) Dissolve a little soda in water and add some dilute acid to the solution. Compare what takes place with what you noticed in the preceding exercise.

(*g*) Fit a small flask with a cork through which pass a thistle funnel and a delivery tube bent twice at right angles, as shown in Fig. 73. Place some soda in the flask. Replace the cork. Pour down the thistle funnel sufficient water to cover its open end. Arrange the end of the delivery tube so that it dips below the surface of some lime water contained in a test tube (Fig. 73). Pour some dilute acid down the thistle funnel. What effect has the gas thus formed on the lime water? What do you think the gas must be? Apply other tests to confirm your idea.

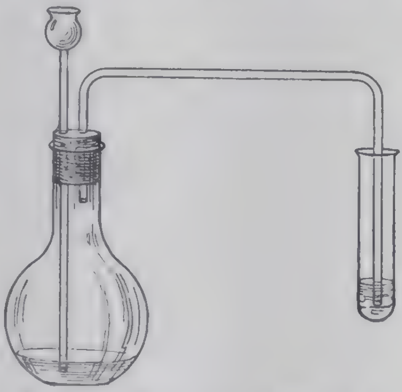

FIG. 73.—Flask arranged for use in Exercise 94 (*g*).

(*h*) Obtain a drop or two of litmus solution. Add to it some water and a few drops of dilute acid. Next add to the liquid some soda solution drop by drop, until you can distinguish a change in the colour of the mixture. Heat the mixture till it boils briskly. Does any further change occur in the colour? If there is no change in the colour, add a few drops more of the solution of soda and boil the liquid again. What double effect does the boiling seem to have?

95. The Preparation and Properties of a "Caustic Alkali."

(*a*) Dissolve about 8 grams of washing soda in a small quantity of water. Heat 500 c.c. of clear lime water in a large flask until it boils. Add to the boiling lime water half the soda solution just prepared. Allow the precipitate formed to settle, then add a few more drops of the soda solution. If there is a further precipitate on adding the second quantity of soda, continue to add the soda, a few drops at a time, until no further precipitate is formed in the solution.

(*b*) Collect on a filter the precipitate formed in the preceding exercise. Preserve the filtrate for use in a later exercise. Wash the precipitate with a stream of water from your wash bottle, and while still on the filter paper, dry the precipitate in a hot air oven. Place the dried solid in a test tube and pour over it a few drops of dilute acid. Observe the action that takes place. Pour the gas which now fills the tube into a test tube containing a few c.c. of lime water, taking care that none of the liquid follows the gas. Close the test tube containing the lime water with your thumb and shake the tube. What forms in the lime water? Of what would this lead you to think the solid you have collected from the lime water consists?

(*c*) Now examine the filtrate which you have kept from Exercise 95 (*b*). Dilute a few drops with water and taste it. Reduce its volume to a quarter by boiling. See what feeling this solution produces when rubbed on your hands or between your finger and thumb.

(*d*) Dilute a drop of litmus solution with water so as to form a solution which has a distinct colour. Add to this a few drops of the filtrate from Exercise 95 (*b*). What effect is produced on the litmus?

(*e*) To a small part of the solution from Exercise 95 (*c*) add a few drops of dilute acid. Does it behave in the same way as the washing soda solution when acid was mixed with it? If gas is given off, add 50 c.c. of lime water and boil again. Allow any solid formed to settle. Continue this until a few drops of the clear solution, when mixed with acid, give off no gas. Does the solution then contain washing soda?

(*f*) You must now prepare a solution containing a larger quantity of the substance the properties of which you have been examining. For this purpose repeat Exercise 95 (*a*), using a quantity of lime "sludge" instead of lime water, since the lime water is only a weak solution of lime. Dissolve 25 grams of washing soda in a sufficient quantity of water. Mix an equal weight of freshly slaked lime into a paste with water. Mix the soda solution with the lime "sludge" in a basin and heat them to boiling, stirring them frequently with a glass rod. Continue to boil until the solution, when freed from solid, gives off no gas on the addition of acid. Allow the solid to settle. Pour the liquid gently into an iron basin so as to leave as much of the solid as possible in the basin. While doing this hold a glass rod against the mouth of the basin so as to direct the liquid into the iron basin (Fig. 19).

Evaporate the filtrate in the iron basin until a solid begins to appear. Set the liquid aside to cool.

> The solid you have thus prepared is known as **caustic soda**, because it has the power of burning the skin, while the "mild alkali"—washing soda—has not. If the solution had been evaporated in a porcelain basin, the caustic soda would have attacked the glaze on the basin.

In writing your account of this exercise do not omit to state of what the white solid you filtered off was composed.

(*g*) Obtain a stick of caustic soda and break a small piece from it by a sharp tap from the back of a knife blade.

Replace the remainder in the bottle and examine the small lump on a watch glass. Do not handle the caustic soda more than you can help. After the caustic soda has been left in the air for some minutes, what do you notice has taken place?

(*h*) Put the remainder of the stick of soda into a test tube half full of water. Does the solid appear to dissolve easily?

(*i*) Wet your fingers with a drop of the solution and rub them together. How would you describe the effect produced?

(*j*) Dilute a drop of the solution with many times its own volume of water. Taste this very dilute solution.

(*k*) Find what effect the strong soda solution has on litmus solution. Acidify some litmus solution with a few drops of acid. Notice the colour. Add caustic soda solution until a further colour change is produced. Describe what you see take place. Compare the results of the last three exercises with what you found in Exercises 95 (*c*), (*d*), and (*e*).

*96. Mild and Caustic Potash.

(*a*) Examine the "mild alkali" potash. Compare this substance with crystals of washing soda. Make a solution in water. Further dilute some of this solution and taste it. Find what effect is produced when a drop is rubbed on the hand. Record these observations carefully.

(*b*) Ascertain what effect acid has on a crystal or two and on a few drops of the solution.

(*c*) Prepare for use the apparatus used in Exercise 94 (*g*). Place in the flask a small layer of the mild alkali you are examining. Then, as in Exercise 94 (*g*), pour down the funnel sufficient water to prevent the escape of gas through its open end. Next add a small quantity of dilute acid. Pass the gas which is formed into lime water. Observe the effect produced. What do you consider the gas to be?

(*d*) Make 25 grams of slaked lime into a thin paste with water. Dissolve in the smallest quantity of water 20 grams of "mild" potash. Mix the potash solution with the lime in a basin and heat the mixture, stirring occasionally. Continue as directed in Exercise 95 (*f*) until the liquid no longer gives off a gas on being mixed with dilute acid. Separate the solid from the liquid by decantation, as you did the solid in Exercise 95 (*f*).

(*e*) Evaporate the filtrate, at first in a porcelain basin, then —when half the liquid has disappeared—in an iron basin. When the liquid becomes thick with solid, set it aside to cool.

The solid thus formed is called **caustic potash.**

(*f*) Procure some caustic potash and examine it in exactly the same way as you did caustic soda in Exercises 95 (*g*) to (*k*).

97. Ammonia.

(*a*) Fill a hard glass tube half full of horn or hoof parings. Instead of these, glue may be used. Heat the tube gently over the Bunsen flame. Smell the gas evolved. Damp a piece of red litmus paper and hold it in the mouth of the tube. What change does the litmus undergo? What is the nature of the gas given off by the horn or glue?

(*b*) Dry 20 grams of sal-ammoniac (ammonium chloride) in a steam oven. Powder it in a mortar and stir with it 30 grams of fresh lime. Cautiously smell the mixture. What do you notice? Transfer the mixture to a wide test tube and place above it a layer of lumps of quicklime (Fig. 74). Fit the tube with a rubber stopper and delivery tube bent at right angles. Arrange the apparatus as shown in Fig. 74 in a fume cupboard. Place over the delivery tube a piece of cardboard pierced with a hole, so as to close the mouth of the gas cylinder in which the gas is collected. When this is ready heat the tube very gently.

(*c*) Hold a piece of moist red litmus paper within the cylinder in which the gas is being collected. What reasons have you for believing the gas to be the same as that prepared from horn or glue?

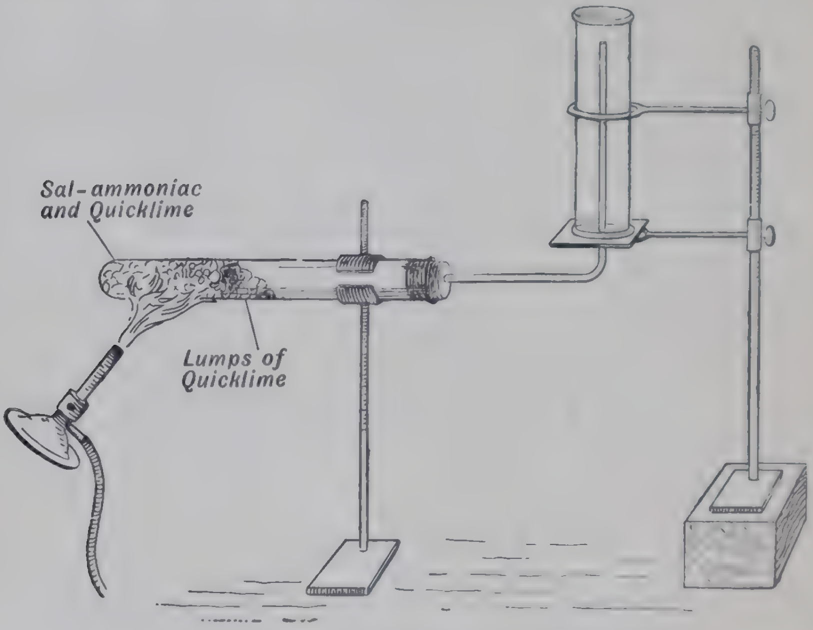

FIG. 74.—Preparation of ammonia.

(*d*) Collect another cylinder full of the gas. Judge when it is full by holding a piece of moistened litmus paper below it. When it is full, hold a lighted taper at the mouth of the jar. Then thrust it up into the gas. What is the behaviour of the gas with regard to combustion?

(*e*) Fill another cylinder with the gas and bring it mouth downwards into water. Remove the cover quickly. What takes place? What do you learn from this?

(*f*) Turn the delivery tube used in Ex. 97 (*b*) downwards and pass the gas into a few cubic centimetres of water contained in a test tube. Observe carefully what takes place. How are you able to tell when the water has dissolved as much of the gas as it can?

(*g*) Fill a flask fitted as described in Exercise 64 (*d*) with the gas. For this purpose clamp the flask inverted and attach to its outlet tube a second tube, as in Fig. 51. Pass the gas which issues from the flask into water. How can you decide that all the air has been expelled from the flask? When all the air has been driven out, close the flask by means of clips and find its weight. Calculate the density of the gas as you did that of nitrogen in Exercise 64 (*d*).

> This gas was commonly made by heating the horn of deer. It was dissolved in water, and the solution was called "spirits of hartshorn." It was afterwards prepared from sal-ammoniac, and therefore called **ammonia.**

(*h*) Dip a glass rod in strong muriatic acid and hold it in the gas which issues from a strong solution of ammonia. What do you notice?

(*i*) Add a drop of litmus solution to a few cubic centimetres of dilute ammonia solution. What is the colour produced? To this mixture add some dilute muriatic acid, a small quantity at a time. What change do you notice?

98. Comparison of Mild and Caustic Alkalies.

(*a*) Draw up a table in the manner indicated below. Fill in the first four columns only at present:

Properties.	Mild Alkalies.		Caustic Alkalies.		Lime.	Ammonia Solution
	Potash.	Soda.	Potash.	Soda.		
Taste						
Feel between fingers						
Action on litmus						
Action of acids on						
Gas formed by action of acids						

(*b*) After filling in the first four columns, write carefully what you consider the chief differences between mild and caustic alkalies.

(*c*) Fill in the last two columns—the properties of lime and of ammonia solution—and decide whether they resemble mild or caustic alkalies.

ADDITIONAL EXERCISES. XVI.

1. Obtain some baryta water, and, after studying its behaviour, decide whether it is a mild or a caustic alkali.

2. Examine some sal-volatile and discover in what respects it resembles washing soda. Discover also what substance is produced when sal-volatile is heated with lime.

CHAPTER XVII.

INTERACTION OF ACIDS AND ALKALIES.

99. The Interaction of Caustic Soda and Muriatic Acid.

(*a*) Dilute 8 c.c. of strong muriatic acid by adding to it a litre of distilled water. Weigh about 4 grams of caustic soda into a flask. Pour over it a litre of distilled water and close the mouth of the flask with a cork. Shake both these solutions repeatedly and make certain that the soda and acid are distributed equally throughout the solutions. *The results obtained throughout this chapter will be worthless unless this precaution is taken always with the solutions used.*

(*b*) Clean two burettes. Fill one with soda solution, the other with the acid. Measure 50 c.c. of soda solution into a flask. Add to this sufficient litmus solution to give it a decided colour. Do not use more litmus than is necessary for this. Note carefully the exact level of the acid in the burette. Add the acid to the soda, a cubic centimetre at a time, shaking at frequent intervals until the colour of the litmus begins to change. When this takes place allow 0·5 c.c. more to enter and again shake the mixture. If the colour has become distinctly red, run in a drop or two of soda solution, noting exactly how much is added, until the liquid in the flask is neither red nor blue. It may be necessary to add more acid before this result is obtained. Note the volume of each liquid which has been used.

(*c*) Place a fragment of zinc in a test tube and pour over it a few drops of the mixture of acid and alkali. Has the solution the same effect as an acid usually has? Rub a drop of the mixture on your hand and compare the feeling with that usually produced by soda solution.

(*d*) Fill in the following table:

	Muriatic Acid.	Soda Solution.	Mixture of Acid and Soda.
Effect on litmus solution			
Effect on zinc			
Feeling of solution			

The solution formed by mixing acid and alkali has neither alkaline nor acid properties. It is called **neutral**. The process is known as **neutralization**.

(*e*) From the numbers obtained in Exercise 99 (*b*), calculate the exact volume of the acid which is required to neutralize 1 c.c. of the soda solution. Measure 10 c.c. of soda solution from the burette and add the volume of acid which, according to your calculation, should just neutralize it. See if this is the case by adding a drop of litmus. If the solution is not neutral, add drop by drop the volume of acid or alkali required to make it so.

Repeat this work a third time and take the mean of the three results. Hence calculate once more the volume of acid required to neutralize 1 c.c. of the soda solution.

(*f*) Measure into a weighed porcelain basin 25 c.c. of the soda solution and add to it the calculated volume of acid required to neutralize the soda exactly. Do *not* add any litmus. Evaporate the mixture to dryness on a water bath.

Complete the drying in an oven and find the weight of solid formed. Repeat this with different volumes of the soda solution, until you can decide whether, from a certain weight of soda, a constant amount of solid is formed. Then examine the solid with the help of a lens. Have you seen any solid like it before? Taste some of it. Determine its solubility in water and its behaviour when heated in a glass tube. Compare it in this way with common salt. Do you discover any differences?

100. Caustic Soda and Oil of Vitriol.

(*a*) Measure 3 c.c. of strong oil of vitriol. Dissolve the oil of vitriol in so much distilled water that the volume of the solution becomes 1 litre. Shake the solution repeatedly so that the acid may be thoroughly mixed with the water.

(*b*) Find the volume of this solution which is required to neutralize 25 c.c. of the soda solution used in Ex. 99 (*b*). Proceed as in Exercise 99 (*b*). From the numbers thus obtained calculate the volume of oil of vitriol solution required to neutralize 1 c.c. of soda solution. Verify this result by taking 10 c.c. of the alkaline liquid and finding if the calculated volume of acid does actually render it neutral. If it does not, find the volume of acid or alkali required to make it so. Repeat this work, and take the mean of three sets of numbers thus obtained.

(*c*) Measure 25 c.c. of soda solution into a weighed porcelain basin, and add the volume of oil of vitriol solution required to neutralize it. Evaporate it as in Exercise 99 (*f*), dry in an oven the solid obtained, and find its weight. When this has been done, examine the solid with the aid of a lens and describe its appearance. Of what does its taste remind you?

> From their resemblance to the common salt obtained from soda and muriatic acid, all solids prepared by neutralizing an alkali with an acid are called **salts**.

(*d*) Repeat the previous experiment so as to find whether in this case also a fixed weight of salt is always formed from the same weight of soda.

(*e*) Calculate in the following manner the volume of dilute oil of vitriol which neutralizes the same volume of the soda solution as 1 c.c. of the muriatic acid used in Exercise 99 (*e*):

1 c.c. of soda solution neutralizes ...... c.c. of muriatic acid.
1 c.c. of soda solution neutralizes ...... c.c. of oil of vitriol.
... c.c. of muriatic acid neutralizes the same amount of alkali as ...... c.c. of oil of vitriol.

In the following exercise see if this holds good for another alkali, potash.

101. Caustic Potash and Acids.

(*a*) Dissolve 5·5 grams of caustic potash in distilled water, observing the same precautions as you did with soda in Exercise 99 (*a*). Make the solution up to a litre. Mix it thoroughly by shaking it.

(*b*) Find the volume of muriatic acid and of oil of vitriol solution required to neutralize 1 c.c. of this potash solution. Proceed as directed in Exercise 99 (*b*).

(*c*) Compare these numbers with those obtained in Exercise 100 (*e*). Do they bear the same relation to one another?

(*d*) Discover whether the product obtained by neutralizing muriatic acid with potash and evaporating is of the same nature as that obtained when the acid is neutralized with soda.

102. The Interaction of Ammonia and of Lime with Acids.

(*a*) Dilute 10 c.c. of strong ammonia solution with 20 times its volume of water. Discover whether it can be neutralized with (i) muriatic, (ii) nitric acid.

(*b*) Determine the volume of the muriatic acid prepared in Exercise 99 (*a*) which is required to neutralize 20 c.c. of ammonia solution prepared in Exercise 102 (*a*). Repeat the work at least three times, and take the mean of these results.

(*c*) Neutralize 20 c.c. of strong ammonia solution with the calculated volume of muriatic acid. Evaporate the solution to dryness on a water bath. Examine it and describe its appearance, taste, etc. Compare these properties with those of sal-ammoniac. Does the solid behave like sal-ammoniac when mixed with lime?

(*d*) Make some lime sludge and mix with it 10 c.c. of strong muriatic acid previously diluted with four times its volume of water. Stir the mixture and separate the solution from the lime which remains by decanting it on to a filter. Is the solution neutral? If it is found to be alkaline, add a drop or two of dilute muriatic acid until it is neutral. Evaporate the solution to dryness, at first over a bare flame, and then on the water bath. Examine the solid formed. Leave a little in the air. What takes place? In what cases have you seen this happen before?

(*e*) Find the volume of the muriatic acid solution prepared in Exercise 99 (*a*) which is required to neutralize 25 c.c. of lime water.

ADDITIONAL EXERCISES. XVII.

1. Prepare a salt by neutralizing ammonia with dilute nitric acid. Compare its properties with those of sal-ammoniac.

2. Dissolve zinc oxide in muriatic acid. Filter the solution and boil away the liquid on a water bath. Compare the solid which remains with the substance obtained from the solution in Ex. 78 (*c*). Dissolve zinc oxide also in dilute

oil of vitriol and reduce the bulk of the solution by boiling, until crystals form when the liquid is allowed to stand. Compare these crystals with those obtained in Ex. 73 (*c*).

3. Find the volume of the oil of vitriol solution prepared in Ex. 100 (*a*) which is required to neutralize 25 c.c. of ammonia solution.

CHAPTER XVIII.

EQUIVALENT WEIGHTS.

103. Metals and Oxygen.

(*a*) From your notes on Exercise 67 (*c*) find what percentage magnesium gains in weight when it combines with the oxygen of the air.

(*b*) Repeat Exercise 67 (*c*), once or twice, until you can decide whether magnesium combines with the same or different weights of oxygen on different occasions.

(*c*) Weigh a piece of very fine iron wire (No. 40) 100 cm. long. Place it in a weighed crucible and heat it for an hour in the muffle furnace (or in the Midget furnace, if the muffle furnace is not available). Allow it to cool in the desiccator and find the increase in weight. Heat it again for half an hour, again allow it to cool, and find if there has been any further increase in weight. Repeat the heating, cooling, and weighing until the weight remains constant on two successive occasions. Calculate the weight of oxygen with which 100 grams of iron combine.

(*d*) Repeat the last exercise with a different length of wire, and decide whether 100 grams of iron combine with the same weight of oxygen on different occasions.

(*e*) Tabulate the results obtained in Exercises 103 (*a*) to (*d*) in the following manner:

METAL.	EXPERIMENT.	WEIGHT OF OXYGEN WHICH COMBINES WITH 100 GRAMS OF METAL.
Magnesium	1	...... grams
	2	...... grams
Iron	1	...... grams
	2	...... grams

(*f*) Decide as far as you can from these results:

(i) Whether 100 grams of one metal (*e.g.* iron) always combine with the same weight of oxygen.

(ii) Whether the weight of oxygen in combination with 100 grams of metal differs according to the metal used.

> The most accurate experiments have shown that when elements, like oxygen and the metals just used, unite to form a definite compound, they always combine together in the same proportions by weight.
>
> This fact is known as the **Law of Constant Proportions**.

104. The Weight of Hydrogen displaced by Metals.

(*a*) Find from your notes on Exercises 85 (*a*) and (*b*) the volume—at 0° C. and 760 mm.—of the hydrogen displaced from dilute oil of vitriol and from muriatic acid by 1 gram of zinc. Calculate the weight of hydrogen displaced in each case.

> One litre of hydrogen at 0° C. and 760 mm. may be taken to weigh 0·09 gram.

(*b*) Calculate in a similar manner the weight of hydrogen displaced from these acids by one gram of iron and by one gram of magnesium.

(*c*) Collect these results in a table as follows:

METAL USED.	ACID.	WEIGHT OF HYDROGEN DISPLACED BY 100 GRAMS OF METAL.
Zinc	Oil of Vitriol	...... grams
"	Muriatic Acid	...... grams
Iron	Oil of Vitriol	...... grams
"	Muriatic Acid	...... grams
Magnesium	Oil of Vitriol	...... grams
"	Muriatic Acid	...... grams

(*d*) After a careful study of the table you have prepared decide:

(i) Whether one gram of a metal (*e.g.* zinc) always turns out the same weight of hydrogen from an acid, whichever acid is used.

(ii) Whether this weight is the same or different in the case of different metals.

105. The Weight of Oxygen which combines with 1 gram of Hydrogen.

(*a*) Calculate the weight of oxygen which is equivalent to 1 gram of hydrogen as shown below:

100 grams of magnesium displace x grams of hydrogen.

100 grams of magnesium combine with y grams of oxygen.

$\therefore$ x grams of hydrogen are equivalent to y grams of oxygen.

1 gram of hydrogen is equivalent to $\frac{y}{x}$ grams of oxygen.

(*b*) From the number thus obtained find the weight of oxygen which is likely to combine with 1 gram of hydrogen.

*106. The Weight of Oxygen in Water.

(*a*) In order to find if oxygen and hydrogen do actually combine in these proportions by weight, repeat Exercise 83 (*b*), determining the weight of oxygen used and of water formed. Obtain the oxygen from oxide of copper instead of red lead. While the apparatus is being prepared, heat gently some coarsely granulated copper oxide in a basin over a Bunsen flame. At the same time dry some coarse-fibred asbestos in a crucible. Get ready for use the apparatus for the preparation of hydrogen described in Exercise 80 (*a*). To the delivery tube of this apparatus connect two drying bottles similar to those used in Exercise 83 (*b*). Obtain a hard glass tube like that described in Exercise 67 (*f*), and fit it in a similar manner. Arrange that each end of the hard glass tube may be closed with a stopper made of a short length of glass rod. See that the tube is clean and dry and that the connections fit tightly.

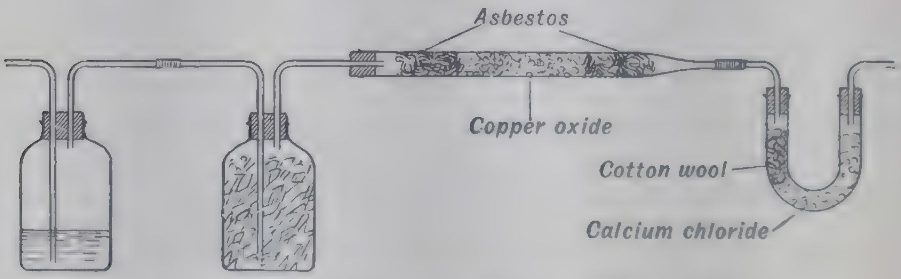

FIG. 75.—Determination of the weight of oxygen in water.

(*b*) In order to collect and weigh the water formed, pass it through a tube containing calcium chloride (a substance which has a great attraction for water). Fit a small **U** tube with rubber stoppers and short glass connecting tubes (Fig. 75). Fit these connecting tubes with rubber tubes and stoppers made of glass rod, so that the outer air may be excluded when the **U** tube is not being used. Pack one arm of the U-tube with cotton wool, the remainder of it with granulated calcium chloride, so as to allow for the passage of gas through it. The wool catches any drops of water which enter the U-tube. Recork the tube and weigh it with its contents.

(*c*) Pack the hard glass tube with the still warm copper oxide, keeping the latter in place at each end with wads of dry asbestos. Replace the tubes with their stoppers. Allow the whole to remain till cool. Remove one stopper for an instant so that the pressure inside the tube may become that of the atmosphere. Replace the stopper and find the weight of the tube and its contents.

(*d*) Connect together the various parts of the apparatus as shown in Fig. 75. Allow hydrogen to pass through till the air has been entirely driven from every part of the apparatus. Test if this is the case by the method used in Exercise 83 (*b*). When this precaution has been taken, begin to heat the copper oxide tube, starting at the end nearer to the hydrogen supply. Use a small flame at first so as to heat the tube very gradually. When the red colour of copper has spread through half the copper oxide, remove the flame and stop the current of hydrogen *completely* for a minute. Allow the hydrogen to pass through again, a bubble at a time. In order to drive out any water which may have collected in the hard glass tube, warm it *very gently* all along, starting at the end nearer the hydrogen apparatus, and gradually moving the flame towards the other end. Continue until all traces of moisture have disappeared from the copper oxide tube and the connecting tubes leading to the calcium chloride tube. If it proves difficult to make all the moisture pass along, heat rather more strongly the part of the hard glass tube where the oxide has all been turned into copper. Finally remove the flame and allow the hydrogen to pass at the same slow rate until the apparatus is cold. Replace the stoppers in both copper oxide and calcium chloride tubes and find their weights. The loss in weight of the copper oxide gives the weight of oxygen used, the gain in weight of the calcium chloride the amount of water formed. Obtain the weight of hydrogen used by subtracting the weight of oxygen from the weight of water. Calculate the weight of oxygen which combines with one gram of hydrogen. Does this agree with your previous calculation?

> The weight of an element which combines with, or takes the place of, one part by weight of hydrogen is called its **combining** or **equivalent weight**. You can now write down the equivalent weight of oxygen.

*107. The Equivalent Weight of Nitrogen.

(*a*) Pass ammonia gas over copper oxide, heated in a tube as in Exercise 106 (*a*). Collect over water, and identify, the gas formed.

(*b*) Determine the composition of ammonia by passing it over red-hot copper oxide and finding the weights of water and of nitrogen formed. Procure the hard glass tube used in Exercise 106 (*a*) and fill it in the same way with copper oxide. Arrange a flask containing strong ammonia solution so that it can be heated on a water bath. Pass the gas through a drying bottle in which is placed: first a layer of broken glass, and on the glass as much quicklime in lumps as the bottle will hold. Connect to the copper oxide tube a U-tube containing calcium chloride, as in Exercise 106 (*b*). In order to measure the volume of nitrogen formed, attach to the U-tube a bottle fitted with a delivery tube like the one used in Exercise 85 (*a*). See that the delivery tube is full of water before beginning. Close the end of both copper oxide tube and calcium chloride tube with stoppers, and weigh them before and after the experiment.

Heat the copper oxide until it is red hot in one place at least. Open the clip on the bottle and warm the ammonia solution by surrounding it with lukewarm water. Continue the work exactly as described in the previous exercise. When the red colour of the copper has spread half way, remove the water bath, allow the tube to cool, and measure the water driven from the measuring bottle. Disconnect the ammonia flask and pass a slow current of air through the apparatus, at the same time gently warming the copper oxide tube. Calculate the weight of nitrogen formed. Weigh the copper oxide and calcium chloride tubes as soon as they are cold.

Weight of copper oxide tube before = ... grams
Weight of copper oxide tube after = ... grams

∴ weight of oxygen used = ... grams

Weight of calcium chloride tube after = ... grams
Weight of calcium chloride tube before = ... grams

∴ weight of water formed = ... grams

Volume of gas collected = ... c.c.
Temperature of water in measuring bottle = ... ° C.
Atmospheric pressure = ... mm.
Corrected volume of nitrogen at 0° C. and 760 mm. = ... c.c.
∴ weight of nitrogen formed = ... grams

Calculate the weight of the hydrogen (i) from the weight of water formed, (ii) from the weight of oxygen used, the combining weights of oxygen and hydrogen being known. Take the mean of these two results as correct. From these numbers calculate the weight of nitrogen which combines with 1 gram of hydrogen.

108. Calculation of the Equivalent Weights of Metals.

(*a*) Calculate the equivalent weight of zinc from the weight of hydrogen which you have found that metal to replace [Exercise 104 (*a*)] in the following manner:

…… grams of hydrogen are replaced by 100 grams of zinc.
∴ 1 gram of hydrogen is replaced by …… grams of zinc.

(*b*) In a similar manner calculate the equivalent weight of magnesium and iron.

> Since very few elements combine directly with hydrogen and most combine with oxygen, their equivalents are often found by calculating the weight of the element which combines with the equivalent weight of oxygen. The equivalent weight of oxygen may be taken as 8.

(*c*) Calculate the equivalent weight of magnesium in the following manner, using the numbers you obtained in Exercise 103 (*b*):

100 grams of magnesium combine with …… grams of oxygen.
∴ ….. grams of magnesium combine with 8 grams of oxygen.
But 8 grams of oxygen are equivalent to 1 gram of hydrogen.
∴ …… grams of magnesium are equivalent to 1 gram of hydrogen.

(*d*) Calculate the equivalent weight of iron by the method described in the last section.

(*e*) Compare where possible the equivalent weights of elements as found by these two methods. In how many cases do they agree with one another?

> Some elements will be found to have two different equivalents. This fact will be explained later.

*109. Determination of the Equivalent Weights of Metals by Replacement.

(*a*) Place about 50 c.c. of blue vitriol (copper sulphate) solution in a beaker. In the solution place two or three iron nails and leave them until you are next working in the laboratory. After examining them describe exactly what you see.

(*b*) In another beaker also containing solution of copper sulphate place a few small pieces of magnesium ribbon. Examine this mixture likewise after the lapse of about a day. What do you find has happened?

(*c*) Repeat Exercise 109 (*b*), weighing the magnesium used and the copper precipitated. Weigh on a watch glass not more than 0·2 gram of magnesium previously cleaned and cut into small pieces. Dissolve in distilled water at least 20 times the weight of copper sulphate. Filter this solution into a small beaker, warm it gently, and place in it the magnesium. Keep the liquid warm and stir it from time to time with a glass rod. Prepare and place in a funnel a small filter paper. When the magnesium has completely disappeared, decant the mixture in the beaker down the glass rod on to the filter, taking great care to lose none of the copper (Fig. 19).

Warm the water in your wash-bottle and wash any pieces of copper which remain on the sides of the beaker into the filter by a jet of water from the wash-bottle. If any pieces stick obstinately to the sides, slip a tiny piece of rubber tube over the end of the glass rod and dislodge them with this.

Finally wash the precipitate on the filter twice with hot water, and then with spirit. Dry the funnel and filter in a steam oven. Remove the filter paper from the funnel, taking great care not to lose any of the copper, and weigh paper and copper, counterbalancing the paper with another of the same size and make. Replace in the oven for another half hour and find whether the weight remains the same. If not, heat again until further drying does not alter the weight.

From the weight of magnesium taken and the weight of copper formed, calculate the equivalent weight of copper.

ADDITIONAL EXERCISES. XVIII.

1. By use of the practical method described in Exercise 109 (*c*) discover what relation the equivalent weights of copper and iron bear to one another.

2. Illustrate the Law of Constant Proportions by describing facts which you have studied in earlier exercises.

3. Determine the weight of hydrogen displaced from muriatic acid by tin in the manner described in Exercise 85 (*a*). Use granulated tin. Add to the strong acid an equal volume of water and a drop or two of platinic chloride solution. The latter enables the action to proceed more easily. Warm the flask. The tin will be found to dissolve slowly.

4. Find the equivalent weight of copper by use of the apparatus described in Exercise 106 (*a*). Take care that the contents of the hard glass tube are quite dry. Weigh the copper oxide placed in it. Reduce the copper oxide by heating it in a stream of dry hydrogen, until it has been *entirely* changed from black to red. Remove any traces of moisture from the tube by continuing to heat it and pass dry hydrogen through it. Finally find the weight of copper remaining in the tube. Hence calculate the weight of oxygen removed.

CHAPTER XIX.

HYDROCHLORIC ACID AND CHLORINE.

110. Preparation and Properties of Hydrochloric Acid Gas.

(*a*) Procure the apparatus used in Exercise 54 (*a*) (Fig. 38) and several gas cylinders with ground glass covers. In order to dry the gas, pass it through a bottle filled with broken glass freshly moistened with strong oil of vitriol (Fig. 65 *a*). Prepare hydrochloric acid gas, as in Exercise 54 (*a*), from rock salt and oil of vitriol.

(*b*) In order to determine the density of the gas, procure an apparatus such as you used in Exercise 64 (*d*). Before filling the flask with the gas, fill five perfectly dry cylinders with it for use in Exercises (*c*) to (*h*). Then proceed to fill the flask in the draught cupboard. As it will be some time before all the air is expelled proceed to the following exercises. Pass the excess of gas from the flask through a long tube into water. See that the rate at which the gas is formed is not allowed to slacken, or the water may be drawn back into the flask. When the bubbles are dissolved entirely in the water, the flask may be regarded as full. Close the clips and weigh the flask. Ascertain the weight and volume of the gas contained in it, as in Exercise 64 (*d*). Calculate the density of the gas.

(*c*) In one of the cylinders containing the gas place a piece of dry litmus paper. After a few seconds remove the litmus paper, wet it, and put it again in the jar. What effect is produced?

(*d*) Leave small pieces of zinc and copper in another cylinder of the gas. Compare the effect produced with that of a solution of the gas on the metals.

(*e*) Damp the metals and leave them in the gas for a few hours. Do you now notice any different result?

(*f*) Dip a glass rod into strong ammonia solution and hold it within one of the jars of gas. What do you observe? Compare this with what you found in Exercise 97 (*h*). Can you account for this result?

(*g*) Place another jar of the gas mouth downwards in water and *quickly* remove the cover. Is any gas left undissolved? If so, the air in the jar had not been completely driven out.

(*h*) Into the gas in other jars insert a lighted taper, a lighted match, and a piece of cotton wool dipped in methylated spirit, and then set on fire. Dip a wisp of wool into turpentine and lower it into the gas. Decide whether the gas is combustible or supports combustion.

m.alg. + Cl_2

111. Preparation of Chlorine.

[illegible]

(*a*) Place in a test tube as much red lead as can be placed upon a threepenny piece. Pour on to this a few c.c. of strong muriatic acid. Warm the mixture gently. Note the colour and smell of the gas formed.

(*b*) In another test tube place a similar quantity of pyrolusite (black oxide of manganese). Again warm gently with strong muriatic acid and observe what happens.

(*c*) What property have the red lead and oxide of manganese in common. For what purposes did you use them in Exercises 70 (*d*) and 71 (*a*)? What substance might both of them give up when brought into contact with muriatic acid?

(*d*) Prepare the gas formed in Exercise 111 (*b*) in larger quantities from pyrolusite (best used in lumps) and concentrated muriatic acid. Use a flask fitted as in Exercise 110 (*a*) and collect the gas by downward displacement, as you did the hydrochloric acid gas; but before collecting it, pass it through a bottle containing broken glass moistened with strong oil of vitriol in order to dry it.

> The gas thus prepared has been named **chlorine** from the Greek word "chloros," which means "greenish yellow."

CAUTION.—*In the exercises which follow, avoid as much as possible inhaling the chlorine. Carry out all the exercises in a fume cupboard.*

112. Properties of Chlorine.

(*a*) Determine the density of chlorine as you did that of hydrochloric acid gas. When the gas which escapes from the flask appears a dull yellow colour the flask may be judged full. To prevent delay while the flask is being filled, proceed with the exercises which follow.

(*b*) Describe the appearance of the gas. Place a flask of the gas mouth downwards in water and remove the cover. After a few minutes, notice how much water has entered the flask. What conclusion do you come to with regard to the power of water to dissolve chlorine? Pass chlorine for some time through water. Keep the "chlorine water" thus prepared.

(*c*) Place inside a jar of chlorine a piece of dry litmus paper. What effect do you notice? Damp another piece and place it inside the same jar. Is there any difference in the effect produced? Does chlorine water also produce this effect? What difference does the presence of water seem to make?

(*d*) Place a piece of paper on which some words have been written in ordinary *black* ink in a jar full of the gas. In the same jar place a piece of newspaper printed with printer's ink. Does the chlorine produce the same effect in both cases? Try also the effect of chlorine water.

(*e*) Try the effect of damp chlorine, or chlorine water, on a number of coloured substances, and find which of these it has the power of bleaching.

(*f*) Arrange a jet of hydrogen so that it can be burnt within a jar containing chlorine.

Be careful to observe the precautions given in Exercise 81 (f) when lighting the hydrogen.

Does the hydrogen continue to burn in the chlorine? Smell cautiously the fumes formed. Bring into them a rod which you have dipped in ammonia solution. What do you consider the fumes to be?

(*g*) Bring a lighted wooden match into a jar of chlorine. Does the match continue to burn? Try whether a taper or candle will burn in chlorine. Dip a piece of cotton wool in spirit and lower it into the gas. Repeat this, using turpentine. What do you notice in these cases? What fumes are formed? Test them with a rod dipped in ammonia solution. Decide how far chlorine is a supporter of combustion.

(*h*) Bring a leaf of Dutch metal (copper beaten into a thin leaf) into a jar containing chlorine. What takes place? Examine the product.

> Compounds formed by the union of chlorine with other elements are called **chlorides**. The substance formed from chlorine and copper is therefore **copper chloride.**

113. Bleaching Powder.

(*a*) Slake a small quantity of lime and place it in a gas cylinder or beaker. Fill the cylinder with chlorine, cover it with a glass plate, and leave it for a time, stirring the lime occasionally with a glass rod. What happens to the chlorine? Pass more chlorine into the cylinder until no further absorption of chlorine is apparent. Remove the lime. Has it altered in appearance? Notice the peculiar smell.

(*b*) Place in a basin a piece of paper on which there are black ink stains or writing. Scatter a little of the bleaching powder you have prepared over the stains. Pour over it very dilute muriatic acid. After a time examine the stains again. What change has taken place?

> Bleaching powder, sometimes called chloride of lime, is also largely used as a disinfectant.

(*c*) Place 20 grams of bleaching powder in a small flask, and almost fill the flask with the strongest ammonia solution. Warm the mixture and collect the gas formed, over water. Examine the gas, and, after comparing with the results of Exercise 107 (*a*), decide what it must be.

> If the other product of this action could be collected, as in Exercise 107 (*b*), it would be found to be water. The bleaching powder, therefore, caused ammonia to take up oxygen.

(*d*) What name is given to a process of this kind where oxygen is supplied to a substance? Decide what class of bodies bleaching powder belongs to? What other substances you know belong to the same class?

ADDITIONAL EXERCISES. XIX.

1. Heat some calcium chloride in a tube with a little strong oil of vitriol. Hold a glass rod which you have dipped in ammonia solution to the mouth of the tube. Decide what gas has been formed from the calcium chloride.

2. Fill a cylinder with chlorine and scatter into it a little

finely powdered antimony. Describe what results and state what is the substance formed.

3. Place a small fragment of phosphorus in a deflagrating spoon and hold it in a jar of chlorine. What action takes place?

4. Decide under what conditions zinc and magnesium combine with chlorine.

5. Examine some "chlorine water" which has been allowed to stand for several days. By what means can you detect the presence of muriatic acid in it?

6. Attach a long jet to the flask in which chloride is prepared (Fig. 76). Fill a jar with hydrogen free from air. Hold the jar of hydrogen mouth downwards and light the gas. At the same instant bring the cylinder over the jet of chlorine, so that the jet passes through the burning hydrogen into the unburnt gas in the cylinder. What takes place? Close the mouth of the cylinder again. Find whether the fumes in the cylinder contain hydrochloric acid gas. Compare this result with what you found in Exercise 112 (*f*).

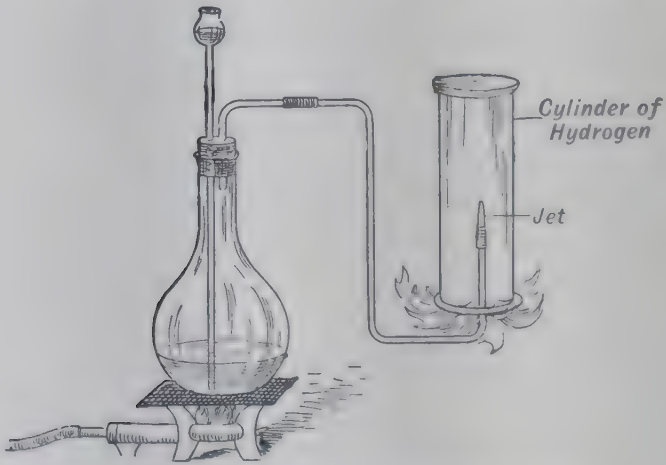

FIG. 76.—Chlorine burning in hydrogen.

In what sense may chlorine be called a combustible substance?

CHAPTER XX.

COMBINATION BY VOLUME. MOLECULAR WEIGHTS.

114. The Electric Current and its Effects.

(*a*) Procure plates of zinc and copper. Connect to each of them a 20 cm. length of cotton covered copper wire. Choose a jar wide enough to receive the plates and half fill it with dilute oil of vitriol (1 part of acid to 8 parts of water). Place the plates in the acid. (Fig. 77.) See that they do not touch one another. Bring the ends of the wires to the tip of your tongue, nearly but not quite touching one another. What taste do you notice?

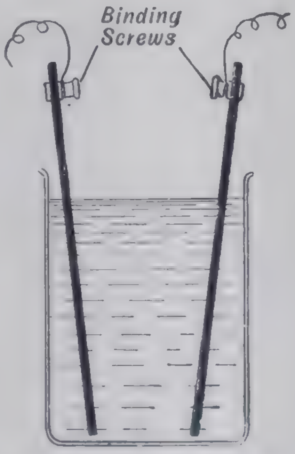

FIG. 77.– A simple voltaic cell.

(*b*) Replace the two wires by a single one. Procure a small compass needle. Place it on a sheet of paper and mark on the paper the direction in which the needle sets itself. Arrange the wire which connects the two plates so that it lies in the direction of the line you have drawn. Bring the compass needle directly over the wire. What effect is produced? Next bring the needle under the wire. What difference is there in the effect?

115. The Electrolysis of Acidified Water.

(*a*) Procure a voltameter. If there is not one available, the apparatus described below will serve the purpose. Cut off the tube of a large glass funnel. Fit the mouth of the funnel with a cork. Procure two pieces of platinum foil (about 4 cm. by 1 cm.) with pieces of platinum wire 7 or 8 cm. long welded to them. Place the pieces of foil within the funnel (Fig. 78). Bore two holes in the cork so that the wires may pass through it as shown in Fig. 78. Pour into the funnel a layer of melted paraffin wax to render it watertight and keep the pieces of foil in position. Over the pieces of foil support two graduated tubes closed at one end. Fill the basin of the voltameter and its two tubes with very dilute sulphuric acid. Connect together at least two Bunsen or Grove cells, carbon plate (or platinum) to zinc. Connect the copper and carbon plates, which finally remain unattached, with the platinum wires of the voltameter.

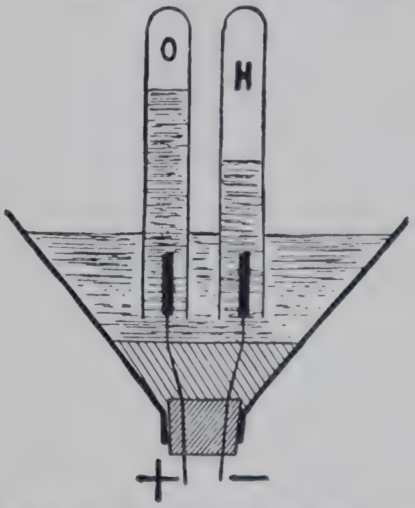

FIG. 78.—Voltameter with platinum electrodes.

The pieces of platinum foil are called **electrodes**.

(*b*) Notice what happens at once when the connection is made. From your previous work [Exercise 83 (*a*)] what do you expect the gases to be? Observe carefully the proportionate rates at which the tubes fill. When one tube is full remove both carefully and test the contents by inserting a lighted match into each. Decide what the gases are and in what proportion they have been formed.

(*c*) From your notes on Exercises 71 (*c*) and 81 (*e*), find which of these gases is more soluble in water. How would this difference in solubility interfere with the accuracy of the result you have just obtained?

A much more accurate knowledge of the volumes of hydrogen and oxygen which combine to form water is obtained by exploding the mixed gases in a tube over mercury. Two platinum wires (Fig. 79) pass through the walls of the tube and just do not meet inside it. The gases are exploded by causing an electric spark to pass between the ends of these wires. It has been found that exactly two volumes of hydrogen combine with one volume of oxygen. If a larger proportion of either gas is present, it is found unchanged afterwards. Usually the steam formed condenses at once to water, which forms no more than a mist on the glass. When, however, the tube is surrounded by a jacket, containing the vapour of some liquid with a higher boiling point than water, and is thus kept above 100° C., the steam cannot condense. It is then found to have the same volume as the hydrogen used—two volumes, in the case just taken.

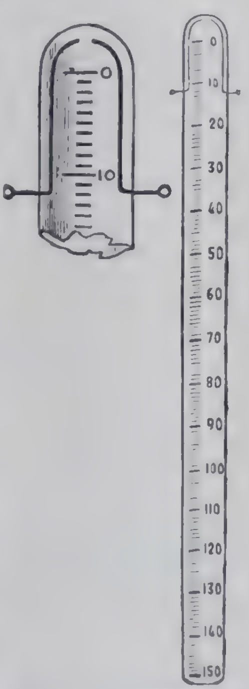

FIG. 79.—A eudiometer.

*116. Composition of Hydrochloric Acid Gas.

(*a*) Procure a voltameter provided with carbon electrodes. The form shown in Fig. 80 is the best for this purpose. Fill the vessel with muriatic acid saturated with common salt, and pass through the acid a current from two or more Bunsen or Grove cells Observe the different rates at which the gases are collected. What possible explanation can you suggest for this fact? Allow the current to pass until gas collects in both tubes. Open the tap above the gas which has collected in quantity and, as you do so, bring a lighted match to the jet. From the effect produced, what do you consider the gas to be? Open the other tap and *very* cautiously smell the gas which issues. Do you recognize the gas?

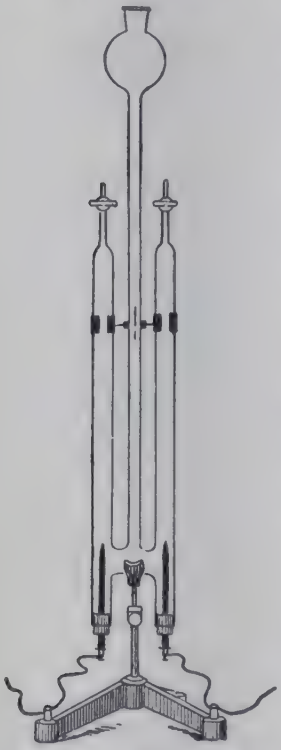
FIG. 80.—Voltameter with carbon electrodes.

(*b*) Remove the apparatus to a draught cupboard and allow the current to pass for several hours, until the acid is saturated with chlorine and the gases are collected without being dissolved. In what proportions are the gases formed?

(*c*) Obtain a glass tube about 1 cm. internal diameter and 70 cm. long. Close it at one end. Choose a rubber stopper which fits tightly into the open end. See that the tube is perfectly dry. Fill it with hydrochloric acid gas, which has been dried by being passed through broken glass moistened with strong oil of vitriol. The gas should be passed in by means of a tube long enough to reach to the bottom of the tube which is being filled (Fig. 81) The experiment must be performed in a fume chamber. When the fumes begin to escape rapidly, withdraw the delivery tube and close the long tube with the stopper. While the tube is being filled, prepare some sodium amalgam.

Sodium is a metal rapidly tarnished by the air and acted on violently by water; it is kept therefore under the surface of a mineral oil like paraffin. It has a violent action on hydrochloric acid. Its solution in mercury, called sodium amalgam, is used in the present exercise, because it acts less violently with hydrochloric acid gas.

CAUTION.—*Remove the sodium from the mineral oil with crucible tongs. Be most careful not to bring it into contact with water and not to touch it with your fingers.*

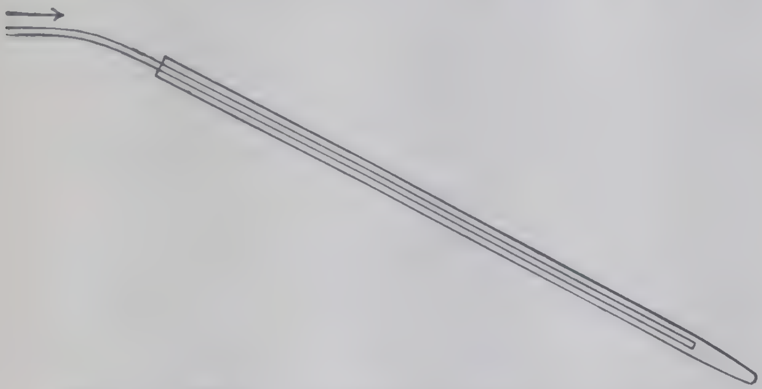

FIG. 81.—Filling a long tube with hydrochloric acid gas.

(*d*) Place the sodium in a dry basin and cut it into pieces half the size of a pea. Gently warm a little mercury in another basin and add the sodium, one piece at a time. Press each piece beneath the mercury with a pestle until it disappears. Add half-a-dozen of the tiny pieces, but stop if there is any sign of them not dissolving completely.

Remove the stopper from the long tube, pour in the amalgam, and at once replace the stopper tightly. Shake the tube thoroughly, and after five minutes open it under water. Allow the mercury to pass out. What volume of gas is left? Notice carefully the relation this bears to the original volume. Open the tube, and at the same time bring a lighted match to the mouth. What does the gas seem to be?

The volumes of hydrogen and chlorine which combine to form hydrochloric acid gas have been determined with great accuracy by passing measured volumes of the gases into a tube and causing them to explode by bringing them into sunlight. When equal volumes of the gases are thus exploded and the tube opened under mercury, no mercury enters. If the tube is opened under water, water enters and fills it. The volume of acid formed is therefore the sum of the volumes of hydrogen and chlorine. If 100 c.c. of hydrogen are mixed with 100 c.c. of chlorine, 200 c.c. of hydrochloric acid gas are formed.

100 c.c. of hydrogen + 100 c.c. of chlorine = 200 c.c. of hydrochloric acid gas.

When ammonia gas is analysed, *two* volumes of it are found to be made up of *one* volume of nitrogen and *three* volumes of hydrogen. To take an example:

100 c.c. of nitrogen + 300 c.c. of hydrogen = 200 c.c. of ammonia.

On these and similar facts Gay-Lussac based his **Law of Volumes**: "When two gases combine there is a simple ratio between their volumes, and also between the sum of their volumes and the volume of gas resulting."

117. Avogadro's Theory.

From experiments which have been performed, it has been seen that all gases behave in a similar way when pressure and temperature are altered [see Boyle's Law, Exercise 61 (*f*), and Charles' Law, Exercise 59 (*b*)]. To explain these facts Avogadro suggested that equal volumes of gases under the same conditions of temperature and pressure contained the same number of particles. These particles Avogadro called **molecules**, for a reason which will be explained shortly.

Avogadro's theory also affords a simple explanation of Gay Lussac's Law of Volumes. Take the case of the combination of equal volumes of hydrogen and chlorine to form hydrochloric acid. Since the volumes of hydrogen and chlorine are equal, and are under similar conditions of temperature and pressure, they contain equal numbers of molecules, while the hydrochloric acid gas resulting contains just twice as many. Suppose the volume of hydrogen taken contains any number of molecules, say one million. Then

$$\left\{\begin{array}{c}\text{1 million mole-}\\ \text{cules of}\\ \text{hydrogen}\end{array}\right\} + \left\{\begin{array}{c}\text{1 million mole-}\\ \text{cules of}\\ \text{chlorine}\end{array}\right\} \text{give} \left\{\begin{array}{c}\text{2 million mole-}\\ \text{cules of hydro-}\\ \text{chloric acid.}\end{array}\right\}$$

$$\therefore \left\{\begin{array}{c}\text{1 molecule}\\ \text{of}\\ \text{hydrogen}\end{array}\right\} \begin{array}{c}\text{com-}\\ \text{bines}\\ \text{with}\end{array} \left\{\begin{array}{c}\text{1 molecule}\\ \text{of}\\ \text{chlorine}\end{array}\right\} \begin{array}{c}\text{to}\\ \text{give}\end{array} \left\{\begin{array}{c}\text{2 molecules}\\ \text{of hydro-}\\ \text{chloric acid.}\end{array}\right\}$$

These facts also give some information about the composition of the molecules of hydrogen and of chlorine. It is evident that each molecule or particle of hydrochloric acid gas must contain some hydrogen and some chlorine. Therefore each molecule of hydrogen and of chlorine must be able to split into two parts. These parts Avogadro called **atoms**, and the compound particles formed by their union he called **molecules** (from a Latin word meaning "little mass").

Therefore, in the act of combination, each molecule of hydrogen divides into two atoms, each of which forms part of a different molecule of hydrochloric acid gas. The symbols H and Cl are used to express one atom of hydrogen and chlorine respectively, and therefore H_2, Cl_2 to express two atoms. The equation

$$H_2 + Cl_2 = 2HCl$$

expresses the results of the union of hydrogen and chlorine to form hydrochloric acid gas. A similar proof can be obtained from the volume of oxygen and the volume of steam obtained from it [Exercise 115 (*c*)].

Since one volume of oxygen combines with two volumes of hydrogen to form two volumes of steam,

$$\left\{\begin{matrix}\text{1 molecule of}\\ \text{oxygen}\end{matrix}\right\} + \left\{\begin{matrix}\text{2 molecules of}\\ \text{hydrogen}\end{matrix}\right\} = \left\{\begin{matrix}\text{2 molecules of}\\ \text{steam.}\end{matrix}\right\}$$

Therefore each molecule of oxygen must divide into at least two atoms, since each molecule of steam contains *some* oxygen. The equation expressing this fact is

$$O_2 + 2H_2 = 2H_2O.$$

(*a*) Draw up a similar proof with regard to nitrogen by use of the numbers obtained from the analysis of ammonia [given after Exercise 116 (*d*)]. Write the equation expressing the facts.

It is usual to express the number of molecules taking part in an equation by a figure on a level with the line, and the number of atoms in a molecule by a figure below the line. Thus $3H_2$ means three molecules, each containing two atoms. Notice that all that is proved is that the molecule of hydrogen or oxygen contains at least two atoms. There is no proof that it does not contain a greater *even* number of atoms, but no fact has been discovered yet which shows that there are more than two. The molecule of hydrogen as expressed by symbol is H_2, not H; that of oxygen O_2, not O. These symbols should not be used vaguely to express indefinite amounts of the gas.

118. Vapour Densities and Molecular Weights.

The weight of a certain volume of gas has been found frequently in previous exercises, but there is no means of ascertaining the number of molecules in such a volume. It is therefore impossible to find the absolute weight of a molecule. But if we assume that Avogadro's theory is correct, it follows that the relation between the weights of the molecules of two gases is the same as the relation between the weights of equal volumes of the gases measured at equal pressures and temperatures. We can therefore compare the weights of the molecules of all gases with the weight of some one molecule taken as a standard. The relative density of a gas compared with hydrogen is called its **vapour density.**

(*a*) Refer to your notes on Exercises 71 (*b*) and 81 (*d*), and proceed to calculate the vapour density of oxygen in the following manner:

Weight of 1000 c.c. of hydrogen at 0° C. and 760 mm. - - - = ... grams
Weight of 1000 c.c. of oxygen at 0° C. and 760 mm. - - - = ... grams
Vapour density of oxygen

$$= \frac{\text{weight of 1000 c.c. of oxygen}}{\text{weight of 1000 c.c. of hydrogen}} = \frac{\text{...... grams}}{\text{...... grams}} = \text{......}$$

(*b*) Calculate the vapour density of nitrogen, chlorine, hydrochloric acid gas, and chalk gas from the values you have found for their densities.

The vapour density of a gas tells us how many times the molecule of the gas is heavier than the molecule of hydrogen; but for molecular weights the standard of comparison generally taken is the *atom*, not the molecule, *of hydrogen*. Since there are two atoms in the molecule of hydrogen,

the molecular weight of a gas = vapour density of gas × 2.

(*c*) Write down the molecular weights of the gases the vapour densities of which you calculated in Exercise 118 (*a*) and (*b*).

CHAPTER XXI.

CARBON AND ITS COMPOUNDS WITH OXYGEN.

119. The Various Forms of Carbon.

(*a*) Place some chips of wood in a crucible, cover closely with the lid and heat them for some time. When the wood is blackened thoroughly, remove the flame. Examine the contents of the crucible and compare them with ordinary charcoal. Is there any difference? Describe the appearance of the charcoal carefully.

(*b*) Hold a piece of porcelain in a flame, such as that of an ordinary bicycle lamp, for a minute. What is formed on the porcelain? Compare lamp black (which is prepared by a similar method) with the deposit. Write anything you know about the uses of lamp black.

(*c*) Examine and describe bone black, prepared by heating bone in a vessel from which the air is excluded; coke, obtained by heating coal in a similar manner; and gas carbon, a deposit found on the sides of the retorts in which coal is heated. Give an account of any purposes for which you know these substances to be used.

(*d*) Procure some graphite. Examine it carefully with the aid of a lens and describe what you see. Compare it with the "lead" in your pencil, and with the "black lead" used for blacking grates.

(*e*) Examine and describe a diamond. Write down its peculiar properties.

120. Properties of Carbon.

(*a*) Determine the density of graphite and of gas carbon by means of a density bottle.

(*b*) Place a piece of charcoal on the surface of water. What information does this give as to the density of the substance? Press the charcoal beneath the surface of the water, and watch what takes place. Can you now suggest a reason for the apparently low density of charcoal?

> The real density of the solid of which charcoal is composed is 1·5.

(*c*) Examine the solvent power of various liquids (*e.g.* water, alcohol, dilute oil of vitriol and muriatic acid) for charcoal, gas carbon, and lamp black.

(*d*) Collect a large test tube full of ammonia gas over mercury (since ammonia is soluble in water). Choose a piece of charcoal small enough to enter the test tube. Hold it with the crucible tongs in a Bunsen flame for some minutes, and when it has cooled somewhat, allow it to finish cooling while pressed below the surface of the mercury. Release it below the mouth of the test tube and let it pass up into the ammonia gas. Describe what you see take place. Can you now explain why the gas escape pipes of sewers are commonly fitted with charcoal filters?

(*e*) Procure a solution of litmus in methylated spirit. Mix with a few c.c. of it an equal volume of water and a small quantity of bone black or animal charcoal, a substance obtained by charring bones. Boil the liquid with the charcoal for a few minutes. Filter it. Is any change in colour noticeable?

> Bone black is used for taking the colour from substances such as brown sugar.

121. The Burning of Carbon.

(*a*) Place a fragment of charcoal in a deflagrating spoon and hold it in the Bunsen flame. When taken from the flame does it continue to burn brightly?

(*b*) Fill a large bottle, as described in Exercise 71 (*a*), with oxygen for use in the following experiments. The oxygen can be obtained from the bottle as required by displacing it with water.

(*c*) Heat a fragment of charcoal, as in Exercise 121 (*a*), and plunge it while still glowing into a jar of oxygen When the charcoal ceases to glow remove the deflagrating spoon and close the jar with a glass plate. Does the burning of charcoal in air differ from that in oxygen?

Hold a lighted taper in the jar in which the charcoal has burnt. What happens? Some gas, not air, now fills the jar. Which of the gases you have studied might it be?

(*d*) Repeat Exercise 121 (*c*), but pour a few drops of lime water into the jar when the deflagrating spoon has been removed. Describe what happens. What other gas produces this effect? Repeat this experiment, burning graphite instead of charcoal. Is the same gas produced?

> Graphite and diamond, although very different in appearance, are composed of the same element as charcoal and lamp black. This element is called **carbon.**

(*e*) Obtain more of the oxide of carbon by burning charcoal in another gas cylinder. Pour some water with a drop of litmus solution into the cylinder. What colour does the litmus become?

(*f*) Prepare another cylinder full of the oxide of carbon. When the charcoal has ceased to glow in the cylinder, remove it and again heat it strongly in the Bunsen flame. Hold it again in the cylinder, and see if it is immediately extinguished. In this way assure yourself that no oxygen is left in the cylinder. Take a piece of magnesium ribbon in the crucible tongs, light it, and while it is burning brightly hold it in the oxide of carbon. Does it continue to burn? Examine the substances left in the jar. Compare the white powder with the substance formed when magnesium burns in air. If it is oxide of magnesium which is left in the jar, from what source can the magnesium have obtained the oxygen necessary to form it? Decide also what the black specks resemble.

(*g*) Write out the series of chemical changes which went on in the previous exercise, stating clearly what substances in succession occupied the jar. Compare the results of the exercise with those of Ex. 91 (*f*).

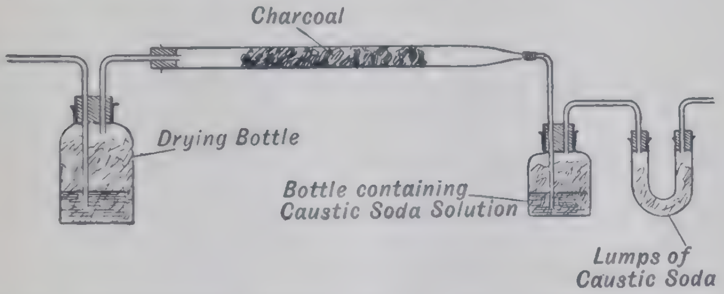

FIG. 82.—Determination of weight of oxygen which combines with carbon.

(*h*) State in two parallel columns the properties of the oxide of carbon studied above, and of chalk gas [Exercise 91 (*i*)]. What name can you now give to chalk gas? Of what then does chalk consist?

(*i*) What other solid substances do you know, of which oxide of carbon forms a part?

* (*j*) In order to determine the weight of carbon and oxygen in this oxide of carbon, pass a stream of oxygen over charcoal. Collect in caustic soda the oxide formed and find its weight. Obtain the weight of carbon used by finding the loss in weight of the charcoal. Arrange the apparatus shown in Fig. 82. Dry the oxygen by passing it through a scrubbing bottle such as you used in Exercise

82 (*a*). Collect the oxide of carbon, which issues from the tube, in a smaller bottle containing fragments of glass and half filled with the strongest caustic soda solution. Absorb any gas which passes through this bottle in a U-tube filled with lumps of caustic soda. Keep these bottles tightly stoppered before and after the experiment, lest they should absorb water or oxide of carbon from the atmosphere. Pack the narrow end of the hard glass tube with carefully dried asbestos. Before packing the hard glass tube with it, heat the charcoal strongly over a Bunsen flame, so as to drive all moisture from it. Take the precaution also of warming the hard glass tube before putting the hot carbon into it, lest you should crack it. After seeing that the connections are tight, pass a slow stream of oxygen over the carbon. Heat the carbon at one point towards the narrow end of the tube only.

Weight of tube and charcoal before being heated = ... grams
Weight of tube and charcoal after being heated = ... grams
∴ weight of charcoal burnt - - - = ... grams

Weight of bottle and U-tube after experiment = ... grams
Weight of bottle and U-tube before experiment = ... grams
∴ weight of oxide of carbon formed - = ... grams

Weight of oxide of carbon formed - - = ... grams
Weight of carbon used - - - - = ... grams
∴ weight of oxygen in ...... grams of oxide of carbon - - - - - - = ... grams

122. The Composition of the Oxide of Carbon.

Exact experiments have shown that when carbon burns, the volume of the oxide of carbon formed is equal to the volume of oxygen used. This shows that every molecule of the gas must contain one molecule of oxygen. The following equation represents the change:

$$C_x + O_2 = C_xO_2.$$

The number of carbon atoms being unknown, so far as you have gone, is represented by x. Since the molecule of the gas contains *two atoms* of oxygen, it is called **carbon dioxide.**

(*a*) Insert the molecular weights of oxygen and oxide of carbon, as calculated from their vapour densities, in the equation given above. Find whether these numbers correspond with the proportions which you found in Exercise 121 (*j*).

(*b*) Calculate the weight of carbon present in the molecular weight in grams of carbon dioxide.

There is no direct method of determining the number of atoms of carbon present in carbon dioxide; but we have no reason for believing there to be more than one. We therefore take $x = 1$ in the formula given above and represent the molecule of the oxide by the symbol CO_2. Since the molecular weight of CO_2 is 44 and that of oxygen is 32, it follows that the weight of the *atom* of carbon compared with that of the atom of hydrogen must be 12.

123. Baking Soda.

(*a*) Prepare a saturated solution of washing soda in water and filter the solution. Pass carbon dioxide through the solution until a quantity of colourless crystals is formed. Separate these at the filter pump.

(*b*) Examine the crystals of baking soda obtained in the previous exercise. Compare them with crystals of washing soda. Determine their solubility in water. How does this differ from the solubility of washing soda? Heat both washing soda and baking soda on the water bath. Decide in what ways these substances differ.

(*c*) Dissolve the baking soda you have thus prepared in water, boil the solution, and collect and test with lime water the gas gradually formed. What is the composition of the gas?

(*d*) From what you have learnt of the preparation and effect of heat on baking soda, decide what its composition must be.

*(*e*) Pass carbon dioxide through a solution of caustic soda and obtain the solid formed in the solution. Examine it and compare it with washing and baking soda. Decide what it is.

(*f*) Heat some dry baking soda in a hard glass tube. Collect and identify the liquid formed.

(*g*) Repeat the previous exercise, and pass the gas given off through lime water. What elements do you thus prove the existence of in baking soda?

124. Carbon as a Reducing Agent.

(*a*) Procure some litharge and mix it thoroughly with finely powdered charcoal. Place the mixture in a hard glass tube, and fit the latter with a rubber stopper and delivery tube bent as in Exercise 42 (*d*) (Fig. 35). Heat the tube and pass the gas evolved through a few drops of lime water contained in a test tube. Decide what is the nature of the gas. Continue to heat the mixture until no more gas is formed. Allow it to cool, and examine carefully the solid left behind. Bearing in mind the composition of litharge, decide what is the nature of the metal beads.

(*b*) Heat copper oxide with charcoal in a similar manner. Is a similar result produced?

(*c*) Decide what effect hot charcoal has on these oxides.

125. The Action of Reducing Agents on Carbon Dioxide.

(*a*) Procure a hard glass tube at least twice as long as those previously used. Pack it with fragments of charcoal. Arrange it so that carbon dioxide may be passed through it. Prepare the carbon dioxide by the method used in Exercise 89 (*a*). Heat strongly the charcoal in the hard glass tube. Pass the gas which leaves the tube through a scrubbing bottle containing broken glass moistened with strong solution of caustic soda. Collect the gas in tubes over water.

(*b*) Reject the first tube collected. Into the second insert a lighted taper. How does the gas differ from the original oxide of carbon?

(*c*) What is the usual action of charcoal on substances containing oxygen? What action do you expect charcoal to have on carbon dioxide, and what do you expect the product to be?

(*d*) Collect another tube full of the gas. Make certain that there is no carbon dioxide mixed with the gas. Set light to it, and when it has burnt replace the cover on the tube. Pour a few drops of lime water into the tube and shake it with the gas. What do you gather from the result?

*(*e*) Pack the tube used in Exercise 125 (*a*) with iron filings instead of charcoal. Arrange the same apparatus as you used in that exercise. Heat the filings as strongly as possible, and pass over them a very slow stream of carbon dioxide. Pass the resulting gas through caustic soda solution to remove any of the original carbon dioxide which may have passed over the filings. Collect the gas and test it as before. Do you find any difference between this gas and that prepared in Exercise 125 (*a*)?

(*f*) Since this gas is formed when oxygen is removed from carbon dioxide, and cannot be carbon itself, what must be its composition? Is your conclusion confirmed by the fact that when the gas itself unites with oxygen it forms the oxide of carbon you know already? Write down a possible formula for the new gas.

From the fact that a molecule of the gas contains only *one* atom of oxygen, it is called **carbon monoxide**, while "chalk gas" is called carbon dioxide.

CAUTION.—Exercises 126 and 127 must be carried out in the draught cupboard, as carbon monoxide is poisonous.

126. Preparation of Carbon Monoxide in Quantity.

(*a*) Heat a small quantity of oxalic acid, mixed with strong oil of vitriol, in a test tube. What effect has the gas given off on lime water? Apply a lighted taper to the mouth of the tube. What takes place?

(*b*) Place about 25 grams of oxalic acid in a flask, and pour in sufficient strong oil of vitriol to cover the solid. Arrange the apparatus so that the mixture may be heated and the resulting gas passed through a scrubbing bottle, such as was used in Exercise 125 (*a*), containing broken glass moistened with strong caustic soda solution. Collect the carbon monoxide in a bottle fitted as in Exercise 71 (*a*).

127. The Properties of Carbon Monoxide.

(*a*) Determine the weight of 1000 c.c. of carbon monoxide. Before filling the flask with carbon monoxide, make certain that the gas contains no traces of carbon dioxide. Calculate the vapour density of carbon monoxide, and hence its molecular weight.

Assuming that the atomic weight of carbon is 12, we can see from its molecular weight that carbon monoxide can contain only one atom, *i.e.* half a molecule, of oxygen. This result is confirmed by the fact that carbon monoxide requires only half its volume of oxygen to convert it to carbon dioxide. The equation is as follows:

$$\begin{array}{ccccc} 2CO & + & O_2 & = & 2CO \\ \text{2 molecules.} & & \text{1 molecule.} & & \text{2 molecules.} \end{array}$$

* (*b*) Find the solubility of carbon monoxide in water. Is its solution in water an acid?

(*c*) Ascertain how far carbon monoxide supports the combustion of various substances, including among these magnesium ribbon.

* (*d*) Pass carbon monoxide through a strongly heated hard glass tube containing copper oxide. What gas is thus formed? Examine the solid left in the tube. What action has carbon monoxide on copper oxide?

(*e*) Review your notes on Exercise 91 on the properties of carbon dioxide (chalk gas), and then fill in the following table:

	CARBON MONOXIDE.	CARBON DIOXIDE.
Density		
Molecular weight		
Solubility in 100 c.c. of water		
Solution acid?		
Burns in air?		
Supports combustion?		
Action on limewater		
Action on caustic potash		

These gases afford the second example you have met with in your work of the **Law of Multiple Proportions,** first stated by Dalton. "When one element forms two or more different compounds with another element, the weights of the first element which combine with a fixed weight of the second bear a simple relation to one another." It is now clear that a substance like carbon or iron can have *two different* equivalent weights [Exercise 108 (*e*)].

(*f*) Compare together the weights of oxygen which combine with one gram of carbon in carbon monoxide and carbon dioxide respectively. Calculate the two equivalent weights of carbon.

ADDITIONAL EXERCISES. XXI.

1. Enclose charcoal in a known volume of air, and thus discover whether air has any oxidizing action on moist charcoal.

2. Heat sodium formate with oil of vitriol and find what gas is produced.

3. Dry small quantities of zinc oxide and powdered charcoal. Heat a mixture of equal parts of the two substances in a hard glass tube and collect the gas formed. Into one tube of the gas pour a few drops of lime water, and shake with the gas. Place the second tube of the gas, mouth downwards, in a solution of caustic soda, and leave it for half an hour, shaking occasionally. At the end of that time close the mouth of the tube with the thumb, and bring it mouth upwards to a lighted taper. From the results of these experiments decide of what the gas from charcoal and zinc oxide is composed.

4. Discover whether red lead can be reduced by carbon monoxide.

CHAPTER XXII.

COMMON ORGANIC SUBSTANCES.

The name "organic" was first applied to substances formed by plants or animals. It is now applied to a much larger class of substances, most of which can be prepared artificially.

128. Sugar.

(*a*) From what plants is sugar obtained? Describe the appearance and crystalline form of white, granulated sugar. Dissolve some brown sugar in water. Boil it with animal charcoal and filter it. What effect is produced? Write down any of the other common properties of sugar which you can make out.

(*b*) Make a solution of sugar in water and find if it has any effect on litmus.

(*c*) Place a few grains of sugar in an iron spoon. Heat the spoon by holding it over a Bunsen flame, as gently as possible at first, afterwards more strongly. Observe carefully the series of changes undergone by the sugar.

(*d*) Arrange a test tube as described in Exercise 42 (*d*) (Fig. 35). Fill a quarter of the tube with sugar which has been carefully dried in a steam drying oven. Heat the sugar and collect the liquid formed in a cooled test tube. Examine the liquid in the test tube. Find its boiling point.

What do you judge the liquid to be? Examine also the nature of the solid left in the tube. Dry it in a crucible over a low flame. What have you learnt about the elements present in sugar?

(*e*) Mix the solid dried in the previous exercise with copper oxide, and place it in a hard glass tube. Heat the mixture and pass the gas formed through lime water for a few minutes. What effect is produced? Remove the test tube containing the lime water and substitute one containing strong caustic soda solution. Is the gas absorbed? Decide the composition of the gas formed when sugar and copper oxide are heated together. Does this give further information concerning the elements present in sugar?

129. Starch.

(*a*) Procure a bag made of calico and place in it about 100 grams of flour. Pour over the flour about 100 c.c. of water and knead the flour for some time under the surface of the water. Remove the bag and dry the solid which is left within it, in a steam oven. Keep this solid for use in Exercise 140. Pour the turbid liquid into a beaker. Examine with a lens the substance which settles after a time in the beaker. Boil a little with some of the liquid in a test tube. Note carefully the change which takes place and the liquid formed.

(*b*) Examine some starch. What appearance has it under the lens?

(*c*) Find whether starch is soluble in cold water. Boil some with water and observe what happens. What is the nature of the liquid formed? Compare starch with the substance formed in Exercise 129 (*a*).

(*d*) Heat a little starch in an iron spoon, as you did sugar, and observe the effect. Does any substance remain after the starch has been heated strongly?

(*e*) Heat starch as you did sugar [Exercises 128 (*d*) and (*e*)] and find what substances are produced.

(*f*) Determine as far as you can of what elements starch is composed.

130. Alcohol.

(*a*) Dissolve 200 grams of sugar in six times its weight of water. Place the solution in a flask and add a little brewer's yeast. Fit the flask with a rubber stopper and delivery tube bent twice at right angles. Place the end of the delivery tube beneath the surface of lime water in a beaker, and leave the whole apparatus for several days in a place the temperature of which is about 20° C. Observe the changes which take place in the liquid. What gas is given off?

(*b*) After some days, filter the liquid in the flask. Distil the clear solution—using for this purpose the apparatus described in Exercise 27 (*b*) (Fig. 17), with a thermometer fitted into the distillation flask. Observe the temperature within the flask from time to time. When the temperature reaches 85° C., remove the distillate. What is the final boiling point? What is the liquid left behind in the distillation flask?

(*c*) In order to absorb some of the water, place in the flask containing the distillate a few lumps of quicklime and set it aside for at least a day. Now decant off the liquid and again distil it. Observe the boiling point as you do so. How does it compare with that of methylated spirit? When the boiling point rises to about 80° C., stop the process.

> The process you have carried out of separating spirit and water by distilling the mixture is called **fractional distillation**.

(*d*) Obtain a retort fitted as in Exercise 82 (*b*) (Fig. 64) for collecting the water formed by burning hydrogen.

Place beneath the retort the flame of a spirit lamp. Collect a little of the liquid formed. Take its boiling point. Decide what the liquid is. What element does this prove the presence of in the alcohol?

(*e*) Allow the spirit lamp to burn in a jar or wide cylinder. After a few minutes remove the lamp and extinguish it. Pour a few c.c. of lime water into the cylinder and shake the lime water with the contents. What gas is present in the cylinder? What second element does this show to be contained in alcohol?

131. Acetic Acid.

(*a*) Place 200 or 300 c.c. of beer in a beaker and set it aside for several days. When a scum or mould is seen to be formed in it, filter it. Compare the properties of this liquid with those of vinegar [Exercise 53 (*a*)] and acetic acid.

(*b*) Neutralize some of the dilute acetic acid thus prepared, with caustic soda solution. Evaporate the neutral liquid until a solid begins to form in it. Set it aside and allow the solid to crystallize. Separate the crystals by means of the filter pump, dry them in the steam oven and examine them. Heat a few of the crystals with strong oil of vitriol. Compare the gas given off with the fumes from hot acetic acid.

132. Oxalic Acid.

(*a*) Examine some crystals of oxalic acid. Are they readily soluble in water? Decide whether alcohol dissolves them more, or less, easily than water.

(*b*) What effect has the solid on blue litmus? Place a piece of blue litmus paper in a solution of the acid in water. Observe the effect.

(*c*) Examine what effect oxalic acid dissolved in water has on washing soda and on chalk.

(*d*) Heat a little oxalic acid on an iron spoon. Describe what takes place.

(*e*) Procure the apparatus described in Exercise 42 (*f*) (Fig. 35). Fill a third of the tube with oxalic acid. Heat the solid, gently at first. Examine the liquid which is condensed in the cooled tube. Decide what it is.

(*f*) Heat the oxalic acid more strongly and collect in tubes over water the gas which is formed. Into the first tube pour a few drops of lime water. What gas is shown to be present? Place the second tube of the gas, mouth downwards, in dilute caustic soda solution. Close the mouth of the tube with your thumb and shake the gas with the soda solution. Wash the soda from your hand after doing this. Repeat this at intervals until on shaking no further amount of the gas dissolves. Then close the mouth of the tube and bring it to a flame. Pour in a small quantity of lime water and note what takes place. Finally decide what were the two gases formed by heating oxalic acid.

(*g*) Dissolve 20 grams of oxalic acid in water and mix with the solution 25 grams of caustic soda. Boil down the solution until a solid crystallizes from it. Separate the crystals. Is their solution in water neutral to litmus?

*(*h*) Procure some salts of sorrel (obtained by boiling down the juice of the sorrel or of rhubarb). Examine the crystals. Are they soluble in water? Make some marks on calico or linen with ordinary black ink (not blue-black). Soak the stains in water and sprinkle over them salts of sorrel. What happens to the stains?

*(*i*) Treat the salts of sorrel as you did the crystals in Exercise 132 (*f*) and examine the gas formed. What do you gather that the crystals contain?

* 133. Tartaric Acid.

(*a*) Examine crystals of tartaric acid and describe their appearance. Dissolve some in water. Are they readily soluble? What effect has the solution on litmus? Has the solid the same effect? Find what effect is produced when the crystals are mixed with baking soda and water is added.

(*b*) Place a few of the crystals in a hard glass test tube and find what is the result of heating them strongly. Collect a tubeful of the gas and shake it with lime water. Pass the gas formed into a cooled test tube. What do you find formed in the cooled tube? Examine also the residue in the hard glass tube. What elements can you prove the presence of in tartaric acid?

* (*c*) Procure the apparatus used in Exercise 132 (*e*). Heat tartaric acid with oil of vitriol. Examine the gases formed and determine what they are. Do you notice any peculiar smell while collecting the gases? Pass the gas for a short time through a few drops of water in a tube. Add a drop of litmus solution to this water. Is the water acid?

* (*d*) Obtain and examine some cream of tartar. Is it easily soluble in water? Is it neutral to litmus?

* 134. Citric Acid.

(*a*) Obtain a lemon and squeeze as much as possible of its juice into a basin. Boil the juice and filter it. Wash the pulp of the lemon with boiling water and pour the washings on to the filter so as to lose as little of the juice as you can. Compare the liquid obtained with citric acid dissolved in water. What action have both liquids on litmus and on powdered chalk?

(*b*) Mix a little citric acid and baking soda together in a test tube. Add a few drops of water. What takes place? Determine the nature of the gas formed.

(*c*) By heating citric acid (i) alone, (ii) with oil of vitriol, find out what elements compose it.

(*d*) Neutralize citric acid with caustic soda and obtain the salt formed.

135. Fats and Oils.

(*a*) Place a quantity of mutton suet in a muslin bag and knead it for some time in a basin of hot water. Examine the tallow which has passed through into the water. What is left behind in the bag?

(*b*) Determine the melting point of tallow as directed in Exercise 36 (*d*).

(*c*) Heat a very small portion of tallow in a hard glass tube and determine what products are formed. What do you gather as to the elements present in tallow?

(*d*) Place about 50 grams of tallow in an iron basin or saucepan and boil it for two or three hours with 100 c.c. of dilute caustic soda solution (1 part of soda to 8 parts of water). Allow the mixture to cool and add a quantity of saturated solution of common salt. Set aside the mixture for a time. Remove and examine the solid which rises to the top. Compare it with common soap.

> The process just carried out, of making a soap from a fat, is called **saponification**.

*(*e*) Obtain some linseed oil. Describe its properties. Smear some on wood and expose it to the air. After some hours compare its appearance with that of olive oil treated in the same way.

*(*f*) Procure some olive oil. Shake it with an equal volume of lime water for some minutes. What takes place?

136. Mineral Oils: Paraffin.

(*a*) Examine some paraffin oil. How does it differ from water in its power of dissolving (i) salt, (ii) fat?

(*b*) Discover whether acids, dilute or concentrated, have any chemical action on paraffin.

*(*c*) Shake paraffin with a solution of caustic soda. Describe what takes place. What does this remind you of?

*(*d*) Attempt to saponify paraffin. Is any soap formed?

(*e*) Discover whether paraffin contains hydrogen or carbon.

(*f*) Examine some paraffin wax. Take its melting point, if you have not already done so. Compare it with liquid paraffin, showing where it resembles and where it differs from it.

137. Gaseous Paraffins. Marsh Gas.

(*a*) Heat in a drying oven 25 grams of sodium acetate, the substance prepared in Exercise 131 (*b*). When the solid is reduced to a white non-crystalline powder mix it with 100 grams of dry soda-lime (a mixture of caustic soda and quick-lime). Fill three parts of a hard glass tube with the mixture and arrange a delivery tube as shown in Fig. 59. Heat the mixture and collect over water the gas formed. Take care in heating that drops of water do not collect and run on to the hot parts of the tube and so crack it. Fill several tubes and afterwards a bottle fitted as in Exercise 71 (*a*) with the gas.

(*b*) Reject the first two tubes of gas collected. Into the third pour a few drops of lime water. Does the gas contain carbon dioxide? Use the next tubeful to decide whether the gas burns or supports combustion. After the experiment again test the gas left in the tube for the presence of carbon dioxide. What do you now know as to the nature of the gas?

(*c*) Is there any result on bringing (i) litmus, (ii) caustic soda, (iii) ammonia into contact with the gas?

(*d*) To the bottle which you have filled with the gas connect a wash-bottle and jet such as you used in Exercise 82 (*a*). Light the jet, observing the same precaution as in Exercise 81 (*f*). Condense the liquids produced in the flame by the device used in Exercise 82 (*b*). Identify the liquid formed. What elements have you now proved the presence of in the gas?

> This gas is formed in stagnant water by the decay of vegetable matter, and has therefore been called **marsh gas.**

138. Coal Gas.

(*a*) Describe the method by which coal gas is prepared, referring if necessary to your notes on Exercise 49 (*f*). What solid is left when the coal is heated?

(*b*) Discover whether the gas supplied in the laboratory contains carbon dioxide. Burn a jet of the gas in a cylinder and ascertain whether carbon dioxide is one of the products of burning.

(*c*) Collect the liquid products of burning coal gas as in Exercise 137 (*d*) and ascertain their composition. What elements have you now proved to be present in coal gas?

(*d*) Repeat Exercise 49 (*f*). Collect the gas produced and shake it with lime water. Remove the delivery tube, dry it and place it within a well-cooled test tube. Describe the substances collected. Can you detect the presence of water among them? Place a small piece of silver, *e.g.* a silver coin, in the gas as it issues from the delivery tube. Observe what happens to the silver.

(*e*) What compounds are present in the gas prepared by heating coal, which are absent in coal gas as supplied for use? Suggest methods by which these compounds may have been removed.

139. Cellulose.

(*a*) Examine and describe some cotton wool. What do you know of its origin? What appearance has it under a powerful lens? Can you explain the name?

(*b*) Try what effect, if any, the following liquids have on cotton wool—does it dissolve in any of them?—(i) water, (ii) alcohol, (iii) oil of vitriol, (iv) muriatic acid.

(*c*) Dry a piece of cotton wool thoroughly. Heat it in a hard glass tube and find out if it contains carbon, hydrogen, or oxygen.

140. Compounds containing Nitrogen.

CAUTION.—*Carry out the following exercises in the fume chamber.*

The residue left when the starch has been extracted from flour is mainly composed of a substance called **gluten**.

(*a*) Heat in a hard glass tube a little of the dried gluten, obtained from Exercise 129 (*a*). Condense the products in a cooled tube. What elements are shown to be present? Examine also the gaseous products. Are they inflammable? Do they contain hydrogen, oxygen, or carbon?

(*b*) Place a fragment of gluten on a platinum foil and heat it strongly. What takes place? Notice the peculiar smell.

(*c*) Mix with copper oxide a little thoroughly dried gluten. Heat the mixture in a hard glass tube and collect the gas formed over a solution of caustic soda to remove the carbon dioxide present. What are the properties of the gas which refuses to dissolve in the caustic soda?

* (*d*) Dry some cheese and examine it as you have done gluten. How far does it seem to resemble gluten?

ADDITIONAL EXERCISES. XXII.

1. Fill a quarter of a test tube with cream of tartar and cover it with strong oil of vitriol. Heat the tube. Collect the gas formed and determine its nature in the manner indicated in Ex. 132 (*g*).

2. Procure the crystals prepared in Ex. 132 (*g*). Dry them in a hot water oven. Heat them with strong oil of vitriol and identify the gases formed.

3. Prepare a specimen of fairly pure alcohol from wine or beer by fractional distillation.

4. Prepare soft soap. Proceed as in Ex. 135 (*d*), but use caustic potash instead of caustic soda. In place of salting out the soap, set the liquid aside after it has been boiled and allow the solid to form slowly.

5. Dry some meat thoroughly and examine it as you did gluten in Exercises 140 (*a*) and (*c*). In what way does it resemble the latter substance?

6. Prepare a hard soap from linseed oil as you did from tallow [Ex. 135 (*d*)].

7. Warm 50 c.c. of a saturated solution of sugar in a beaker. Place the beaker in a sink and pour into it 50 c.c. of strong oil of vitriol. Examine the solid left in the beaker after the vigorous action is over. What does it seem to be? Notice the smell produced and describe it if possible.

CHAPTER XXIII.

COMPOUNDS OF NITROGEN.

141. Nitric Acid.

(*a*) Write a short account of what you have already learnt of the preparation and properties of nitric acid. In what way does it differ from all other acids which you have studied?

(*b*) Place in a small crucible enough sawdust to cover the bottom. Let a few drops of concentrated nitric acid fall on it. Remove it to a fume cupboard and heat it on the sand bath with a low flame. Observe what takes place.

(*c*) Place a few pieces of zinc in a crucible. Pour over them about 5 c.c. of concentrated nitric acid and heat the mixture in the fume cupboard on a sand bath until fumes are formed. Take away the flame when this occurs. Compare the fumes with those formed in Exercise 141 (*b*). When the action has ceased, heat the crucible again until no more fumes seem to be formed. Then heat the crucible with a bare flame for ten minutes. Allow the white substance to cool. While this is taking place study the action of dilute nitric acid on zinc. Notice the nature of the fumes. Evaporate the liquid thus formed over steam until crystals are obtained from it, as it cools. Compare these crystals with the product of the strong acid and zinc. Are they equally soluble in water? Do they appear to be the same, or different substances?

142. The Nitrates.

(*a*) Dilute some strong nitric acid with three times its volume of water, and add to it a dilute solution of caustic soda, in small quantities at a time, until the mixture is neutral or slightly alkaline. In order to ascertain when the mixture is neutral, remove a drop of it on the end of a glass rod and place it on a piece of litmus paper. Evaporate the solution to dryness and examine the crystals formed.

(*b*) Dilute some strong nitric acid with three times its volume of water. Add to this dilute acid a strong solution of ammonia until the mixture smells strongly of ammonia. Evaporate the liquid over a low flame until its bulk is reduced to one third. Continue the evaporation on a steam bath until no liquid is left. While this is going on proceed to Exercise 142 (*c*). Examine the solid formed and preserve it for use in Exercise 144 (*a*).

(*c*) Examine the action of cold dilute nitric acid on zinc. Describe the gas formed. Is it hydrogen? What effect has the gas on a glowing splinter? Evaporate the solution which remains after the zinc has dissolved and obtain the solid which it contains.

(*d*) Place some scraps of lead in a test tube and pour over them some dilute nitric acid. Does any action take place? If it does not begin at once, warm the mixture slightly. Describe the gas given off. Does it appear to be the same as that formed in the previous exercise? Collect some of it and discover its effect on a glowing splinter. Procure the solid which is formed from the solution.

(*e*) Examine in a similar manner the results of bringing together copper turnings and nitric acid diluted with its own volume of water. Notice carefully the properties of the gas formed. Obtain crystals from the solution.

143. The Oxides of Nitrogen.

N.B.—*Carry out the experiments in this section in the fume cupboard.*

(*a*) From your notes on Exercise 142 (*e*) recall the action of nitric acid on copper.

(*b*) Prepare the apparatus shown in Fig. 62. Place in the flask 20 grams of copper turnings. Measure 60 c.c. of concentrated nitric acid, and dilute it with an equal volume of water. Pour down the thistle funnel with which you have fitted the flask a sufficient quantity of the dilute acid to cover the end of the funnel. Collect the gas formed in tubes over water. If the mixture in the flask becomes hot, cool the flask by standing it in water. Notice how the colour of the gas in the flask changes as the air is expelled. What is the colour of the gas first collected in the tube? When half a tube of the gas has been collected, remove it from the trough and shake it with the water left in the tube, without allowing any to escape. Replace the tube mouth downwards in the trough, and notice if any of the gas has been dissolved. Write an account of the properties of the gas so far as you have discovered them. Set aside the liquid in the flask for use in later exercises.

> For reasons which will be seen later, this gas has been named **nitric oxide**.

(*c*) In order to prepare nitric oxide in larger quantities, dissolve a mixture of 90 grams of ferrous sulphate (green vitriol) and 20 grams of nitre in as little water as possible. Place the solution in a flask fitted as in Exercise 73 (*a*). Pour a small quantity of strong oil of vitriol through the thistle funnel, and heat the mixture. Collect the gas in tubes over water until you obtain a tubeful free from red fumes. Add further quantities of strong oil of vitriol as required.

(*d*) Procure a flask fitted as described in Exercise 64 (*d*). Weigh the flask and fill it with nitric oxide, passing in the gas until no red fumes are seen in the flask. Determine the density of nitric oxide, and hence its molecular weight.

(*e*) Taking the atomic weight of oxygen as 16 and that of nitrogen as 14, find the number of oxygen and nitrogen atoms in a molecule of nitric oxide. Write the symbol which expresses one molecule of nitric oxide.

(*f*) Ascertain whether ordinary combustibles, such as a taper and coal gas, will burn in nitric oxide. Is the oxide itself combustible? Observing the usual precautions [Exercise 66 (*c*)], place a tiny piece of phosphorus in a deflagrating spoon. Set fire to it by holding it over a flame and, while it is burning brightly, introduce it into a jar of nitric oxide. Does it continue to burn? Will sulphur burn in the gas?

(*g*) Dissolve in half a test tube of water a crystal of green vitriol [the solid prepared in Ex. 74 (*c*)]. Pass a few bubbles of nitric oxide through the solution. What takes place?

(*h*) Fill a bottle such as you used in Exercise 71 (*a*) with oxygen, for use in the following exercises. Invert a tube full of water in the pneumatic trough. Half fill it with oxygen, and mark the exact volume of the oxygen. Pass in nitric oxide, a bubble at a time. Note what happens as each bubble enters. Shake the gas in the tube with the water after each bubble enters, taking care that none of the gas is lost. Replace the tube in the trough. What change is there in the volume of the gas? Continue this process until the addition of another bubble increases the volume instead of diminishing it. What evidence have you that a new gas, neither oxygen nor nitric oxide, is formed when the two are mixed?

(*i*) Obtain two graduated gas tubes. If these are not available, use ordinary tubes about 2 cm. in diameter and 30 cm. long, and closed at one end. Half fill the tubes over water, one with oxygen and the other with nitric oxide. Mark the exact volume of gas in each. Allow bubbles from the tube of oxygen to mix with the nitric oxide, until all the nitric oxide has been converted into red fumes and dissolved. Allow none of either gas to be lost. When the addition of a bubble of oxygen does not cause any more nitric oxide to be dissolved, stop the process and note what volume of oxygen has been used. Hence determine what are the volumes of oxygen and nitric oxide which have combined.

> Since the red gas contains more oxygen than nitric oxide, it is called **nitrogen peroxide**. The prefix "per" indicates the presence of a larger proportion of oxygen. At high temperatures the density of nitrogen peroxide is found to be 23.

(*j*) Calculate the molecular weight of nitrogen peroxide. With the knowledge that it contains a greater proportion of oxygen than nitric oxide, decide how many oxygen and nitrogen atoms are present in the molecule of nitrogen peroxide.

(*k*) Prepare nitrogen peroxide in larger quantity by mixing nitric oxide with half its volume of oxygen.

(*l*) Ascertain whether a taper, magnesium ribbon, sulphur, and phosphorus will continue to burn in nitrogen peroxide.

CAUTION.—*Observe the usual precautions in handling phosphorus.*

(*m*) Dissolve a quantity of nitrogen peroxide in half a test tube of water. What action has the solution on litmus?

144. Nitrous Oxide.

(*a*) Fit a small flask with a wide delivery tube, about 1 cm. in diameter (Fig 83). Place in the flask 15 grams of ammonium nitrate [the substance prepared in Ex. 142 (*b*)]. Fill the pneumatic trough with hot water, since the gas to be collected is less soluble in hot water than in cold.

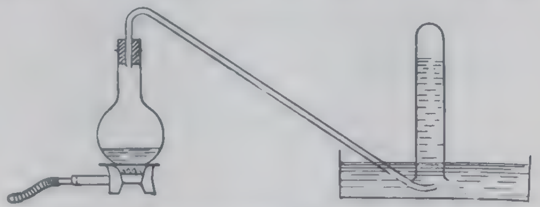

FIG. 83.—Preparation of Nitrous Oxide.

CAUTION. — *Carry out the directions which follow exactly.*

Heat the ammonium nitrate cautiously with a low flame, and notice carefully what happens. As soon as a gas begins to be evolved, remove the flame *immediately.* Fill half a dozen tubes with the gas, and only heat the solid again, very cautiously, as further quantities of the gas are required.

(*b*) Mix the gas with a few bubbles of oxygen. Is any nitrogen peroxide formed? If so, shake the gas with water until the red fumes are dissolved. Repeat this until no red fumes are formed on the addition of oxygen. Allow bubbles of the gas which remains to pass up another tube filled with green vitriol solution. In what ways can you distinguish between the new gas and nitric oxide?

(*c*) Into another tube of the gas pass one or two bubbles of nitric oxide. If red fumes appear they may be formed from the air carried over from the flask. Dissolve them by shaking them with water. Add more bubbles of nitric oxide. Finally decide whether the new gas, if free from air, forms red fumes when mixed with nitric oxide.

(*d*) In order to determine the density of the gas, fill a flask fitted as in Ex. 64 (*d*). Use the knowledge gained in Exercise 144 (*c*) to discover when the gas which passes from the flask is free from air.

(*e*) From your knowledge of its density, calculate the molecular weight of the gas.

Two volumes of this gas are found on analysis to contain one volume of oxygen and two volumes of nitrogen.

(*f*) Write the equation which expresses this separation of the gas into nitrogen and oxygen. From your knowledge of the molecular weight of the gas, decide how many atoms of nitrogen and oxygen the molecule of the gas contains.

> The name **nitrous oxide** is given to this gas to indicate that it contains a smaller proportion of oxygen than nitric oxide.

(*g*) Collect several tubes of nitrous oxide. Into one tube insert a glowing splinter; into another a piece of burning paper. Try also the effect of the gas on the combustion of a taper and on that of burning magnesium ribbon and of brightly burning phosphorus. (N.B. *Remember the precautions to be observed in the last case.*)

(*h*) Discover what difference there is in the effect of nitrous oxide on the combustion of (i) sulphur which is burning brightly, (ii) the same substance which is only just alight. See if the same result is noticeable in the case of charcoal.

(*i*) Make out a comparative table showing the properties of nitrous oxide, nitric oxide, and nitrogen peroxide.

PROPERTIES OF	NITROUS OXIDE.	NITRIC OXIDE.	NITROGEN PEROXIDE.
Appearance			
Solubility in water			
Molecular weight			
Does phosphorus burn in it?			
Does sulphur burn in it?			
Does magnesium burn in it?			
Does it rekindle a glowing splinter?			

ADDITIONAL EXERCISES. XXIII.

1. Determine the solubility of nitric oxide in water.

2. Determine the percentage of oxygen in air by adding nitric oxide to a known volume of air and dissolving the nitrogen peroxide formed in water.

3. Prepare some lead nitrate by dissolving lead in nitric acid. Boil off the liquid and dry the lead nitrate. Heat the lead nitrate in a hard glass tube and discover what is the composition of the gas thus formed.

4. Find what is the composition of the gas formed by dissolving zinc in dilute nitric acid.

CHAPTER XXIV.

SULPHUR AND ITS COMPOUNDS.

145. Sulphur.

(*a*) Procure and examine some roll sulphur. Determine its density. Decide whether it is soluble in water and in alcohol.

(*b*) Place in a test tube an inch-deep layer of powdered sulphur. Heat it in the Bunsen flame, very gently at first. When the sulphur is melted take the tube from the flame and describe the liquid formed. Then resume the heating, noting exactly the changes in the liquid.

(*c*) Procure a large beaker full of water. Heat the melted sulphur from Exercise 145 (*b*) until it begins to boil, and then pour it slowly into the beaker. If the sulphur in the tube catches fire, extinguish it by holding a wet duster to the mouth of the tube.

(*d*) Remove the sulphur from the water and compare it carefully with roll sulphur. What differences do you notice? Is it crystalline? Leave it for a few days. What change has taken place?

(*e*) Melt in a basin sufficient roll sulphur to fill it. Allow the sulphur to cool until a thin crust forms on the top of it. Directly this happens, break two holes in the crust and pour into another basin the sulphur which still remains molten. When the sulphur is cool, detach the crust with a knife and examine the crystals which have formed beneath it.

(*f*) Place in a test tube a half-inch layer of sulphur. Heat it so that it boils gently for a few minutes. What is formed near the mouth of the tube? When it has cooled, remove some of the deposit from the mouth of the tube. Examine the deposit with the aid of a lens. What appearance does it present?

(*g*) Roll up and push into the tube used in the last exercise a piece of copper wire or turnings, so that it is fixed a short distance above the sulphur. Heat the sulphur to boiling until the copper begins to glow. When the action is over, allow the tube to cool. Remove the product and compare it with the copper and sulphur from which it was formed. In what ways does it differ from them?

(*h*) Rub a silver coin with powdered sulphur moistened with water. Leave the sulphur on the coin for some days. What evidence have you that a compound of silver and sulphur is formed?

(*i*) Mix 4 grams of iron filings with half their weight of sulphur. Heat the mixture gradually in a test tube. Keep the sulphur boiling gently for some minutes. When the tube is cool, examine the substance formed. Compare it with iron filings.

> The products formed by the combination of sulphur with other elements are called **sulphides**.

Keep the sulphides just made for use in later exercises.

146. An Oxide of Sulphur.

(*a*) Set light to a piece of sulphur in a deflagrating spoon and allow it to burn in a gas cylinder. When the sulphur goes out, light it again and replace it in the cylinder. Does it continue to burn? Light it again and bring it back into the cylinder until it will not burn any more. Note the appearance, and carefully smell the gas which now fills the cylinder.

(*b*) Discover whether combustibles such as a taper will burn in the gas. What constituent of the air was used up in the burning of the sulphur? Decide what is the probable composition of the new gas. Does the gas itself burn when lighted?

(*c*) Shake the gas thus formed from burning sulphur with water coloured with neutral litmus solution. What effect is produced on the litmus?

(*d*) Procure a flask fitted with a thistle funnel and a tube bent twice at right angles (Fig. 38). Place in the flask 10 grams of copper turnings and pour down the thistle funnel sufficient strong oil of vitriol to cover the metal. Heat the acid until it boils and collect a cylinder of the gas formed, as shown in Fig. 38. Lower the flame as soon as the gas is being given off freely, so that the liquid may not froth over. Examine the contents of the cylinder and compare them with the gas formed when sulphur burns in air. Note the smell and the action of the gas on litmus solution. Discover whether sulphur will burn in the gas.

Does there seem to be any difference between this gas and the gas prepared in Exercise 146 (*a*)?

(*e*) Prepare this oxide of sulphur as directed in Exercise 146 (*d*) and determine its density. Calculate its molecular weight.

> It is found that, when sulphur burns in oxygen, the volume of the oxide formed is equal to that of the oxygen used.

(*f*) Decide how many atoms of oxygen there are in one molecule of this oxide of sulphur. From your knowledge of the molecular weight of the oxide calculate what proportion by weight of sulphur is present in one molecule.

> From the number of oxygen atoms contained in a molecule of the gas, this oxide is named **sulphur dioxide.**

The atomic weight of sulphur is 32. How many atoms of sulphur are present in one molecule of sulphur dioxide?

(*g*) Pass the sulphur dioxide prepared as in Exercise 146 (*d*) into a test tube containing 2 c.c. of water. Notice carefully what happens to the bubbles of gas. When they seem to be no longer dissolved, add caustic soda to the solution, a few drops at a time, until the liquid is just neutral. Heat a few drops of the neutral solution on a watch glass. Examine the solid which remains when the liquid has been driven off. Evaporate to dryness the remainder of the solution in a basin.

(*h*) Describe the solid formed in the last exercise. Taste a grain of it. What class of substances does it seem to resemble? Place a small quantity of the solid in a test tube and pour on it a few drops of strong oil of vitriol. Smell the fumes given off. Hold a piece of damp blue litmus paper to the mouth of the tube, taking care that it is not touched by any oil of vitriol. What effect have the fumes on the blue litmus? Decide what the fumes are.

(*i*) Place some flowers of different bright colours and some green leaves in a cylinder filled with sulphur dioxide. What changes take place?

(*j*) Prepare a strong solution of sulphur dioxide in water. Add to half of it a few drops of baryta water.

> Baryta is a caustic alkali closely resembling lime. Its solution in water is called **baryta water**.

What is formed in the solution? Discover whether the precipitate is dissolved by adding dilute muriatic acid to the solution.

Allow the other half of the sulphur dioxide solution to stand in an open beaker until required in the following section.

147. Oil of Vitriol.

(*a*) Write a short account of what you already know of the properties, physical and chemical, of strong oil of vitriol.

(*b*) From work which you have already carried out decide what is the usual effect of metals on dilute oil of vitriol. How far is copper an exception to the rule? Does strong oil of vitriol behave in the same way with metals?

(*c*) Place a few smears of strong oil of vitriol on a piece of paper. Hold the paper at some height above a gas flame and note what occurs. What substance seems to be formed from the paper?

(*d*) Prepare a strong solution of sugar in water. Place a test tube full of the solution in a fairly large beaker. Stand the beaker in a basin and pour into the sugar solution an equal volume of strong oil of vitriol. What substance appears to be formed? Can you also detect what gas is given off?

(*e*) Add to a dilute solution of oil of vitriol a few drops of baryta water. What takes place? Is the precipitate thus formed soluble when dilute muriatic acid is added? Compare this with what you found in Ex. 146 (*j*). How can you use what you have learnt in this exercise to distinguish between oil of vitriol and the acid solution of sulphur dioxide in water?

(*f*) Procure the solution of sulphur dioxide prepared in Exercise 146 (*j*) which has stood for several days. Test it by means of baryta water to see if it now contains any oil of vitriol.

(*g*) Pour a shallow layer of sulphur dioxide solution, freshly prepared, into a gas cylinder. Into the cylinder above the liquid pass the fumes from boiling nitric acid. Shake the brown fumes with the solution. Repeat this several times, and then examine the solution and ascertain whether it now contains any oil of vitriol.

> The solution of sulphur dioxide in water is called **sulphurous acid**. The name *sulphuric acid* is given to oil of vitriol in order to indicate that it contains more oxygen than *sulphurous acid*.

(*h*) Neutralize dilute sulphuric acid with caustic soda solution. Evaporate the solution and obtain from it the salt formed. Examine the salt and compare it with the salt formed from sulphurous acid in Exercise 146 (*g*). Discover what effect strong sulphuric acid has on this salt. Is any sulphur dioxide formed in this case?

> The salts of sulphur*ous* acid are called sulph**ites** in order to distinguish them from the salts of sulphur*ic* acid which are called sulph**ates**.

(*i*) Collect from Exercises 73, 74, and 100 (*c*) the facts you have already discovered concerning the preparation and properties of the salts of sulphuric acid.

148. Hydrogen Sulphide.

(*a*) Procure the iron sulphide prepared in Exercise 145 (*i*). Place some of the powder in a test tube and cover it with strong muriatic acid. Notice the smell of the gas formed.

> The gas thus prepared is a **sulphide of hydrogen**.

(*b*) Prepare the gas in larger quantity from commercial iron sulphide and dilute sulphuric acid. Fit a flask with a thistle funnel and bent delivery tube and fill several cylinders with the gas over warm water (Fig. 62). The gas is less soluble in warm water than in cold.

(*c*) Into a cylinder filled with the gas pour a few c.c. of strong nitric acid. Cover the mouth of the cylinder with a glass plate. Tilt the vessel so that the strong acid runs over the sides of the cylinder and is brought in this way into contact with the gas. What does the deposit on the walls of the cylinder resemble?

(*d*) Fill a cylinder with sulphur dioxide. Place this mouth to mouth with another cylinder filled with hydrogen sulphide and remove the lids from between the cylinders. Describe the appearance of the visible product.

(*e*) Bring a lighted taper into a cylinder of hydrogen sulphide. Does the taper continue to burn in the gas? Is the gas itself inflammable?

(*f*) Collect hydrogen sulphide in a cylinder which has been previously carefully dried. In order to fill the cylinder with gas cover it in the manner described in Exercise 54 (*a*) (Fig. 38). When the cylinder is full, set fire to the gas. What product do you notice on the walls of the cylinder in addition to the yellow powder? What explanation can you give of this product?

(*g*) Mix together a cylinder of hydrogen sulphide and one of chlorine in the manner described in Exercise 148 (*d*). Bring a glass rod which has been dipped in a solution of ammonia into the white fumes formed in the cylinders. Smell the fumes. What do they appear to be? What other product of the reaction is left on the walls of the cylinders? Describe as accurately as you can the changes which have taken place.

(*h*) Leave a piece of copper and a piece of lead in a jar containing hydrogen sulphide for a day or two. Is any effect produced on the metals?

(*i*) Place a silver coin in hydrogen sulphide for some time. Explain the effect which the gas has on the silver. Compare this with the result of rubbing silver with sulphur. Carry a piece of rubber in the same pocket as a silver coin for a few days. What evidence have you for the presence of sulphur in the rubber?

(*j*) Moisten a slip of white blotting paper in a solution of lead nitrate. Hold it in a stream of hydrogen sulphide. What happens to the paper?

(*k*) Place in a test tube the copper sulphide prepared in Ex. 145 (*g*). Pour over it a little muriatic acid and warm the mixture. Hold in the mouth of the tube a piece of the paper used in the previous exercise. What evidence have you of the formation of hydrogen sulphide?

(*l*) Place in a test tube a small piece of lead foil and pour over it one or two cubic centimetres of nitric acid diluted with its own volume of water. Warm the mixture gently until the lead has dissolved. Half fill the test tube with water and pass through the solution a slow current of hydrogen sulphide. Describe what takes place. What do you imagine the precipitate to be? Separate some of the precipitate from the liquid by filtration and discover whether it is soluble in dilute muriatic acid.

(*m*) From your notes on Exercise 69 (*c*) recall the composition of litharge. Dissolve a few grains of litharge in muriatic acid. When the oxide has been dissolved, dilute the acid with several times its volume of water. Pass through the dilute solution a stream of hydrogen sulphide. Compare the effect produced with what you noticed in Exercise 148 (*j*).

(*n*) Dissolve a few pieces of copper turnings in nitric acid. Dilute the solution with water and pass through it a slow stream of hydrogen sulphide. Compare the result with what you saw in Exercise 148 (*h*).

(*o*) Procure a crystal of the green vitriol which you prepared in Exercise 74 (*c*). Dissolve it in water and add a little dilute muriatic acid. Pass hydrogen sulphide through the solution. Add sufficient ammonia to neutralize the muriatic acid. What result is visible?

(*p*) Dissolve zinc in dilute muriatic acid. Pass hydrogen sulphide through the solution. Neutralize the acid with ammonia. What effect is now produced? Repeat the exercise, using zinc sulphate [prepared in Exercise 73 (*c*)]. Dissolve the zinc sulphate in water. Add a little muriatic acid to the solution, and pass hydrogen sulphide through it. Is any precipitate formed under these conditions? Add sufficient ammonia to make the solution alkaline, and note what happens.

(*q*) Repeat the previous exercise with magnesium in place of zinc and note the results.

(*r*) Classify the sulphides of lead, copper, iron, zinc, and magnesium into three groups—(*a*) insoluble in acid solution; (*b*) soluble in acid solution, but insoluble in alkaline solution; (*c*) soluble in both acid and alkaline solution.

ADDITIONAL EXERCISES. XXIV.

1. Heat together coarsely powdered sulphur and concentrated sulphuric acid in a boiling tube. What is the gas formed?

2. Procure a solution of barium chloride, the salt obtained by neutralizing muriatic acid with baryta. Add to a few drops of the solution some dilute solution of sodium sulphate. Decide what is the substance formed.

3. Dissolve in boiling distilled water a gram of mercuric chloride. Pass hydrogen sulphide through the solution. Identify the substance formed. In a similar way bubble hydrogen sulphide through solutions of aluminium sulphate, calcium chloride, tin chloride, and ammonium chloride. In each case where a sulphide is precipitated, classify it in the way indicated in Ex. 148 (*r*).

4. Procure some sodium thiosulphate and pour on it in a test tube a little muriatic acid. Identify if possible both the gas and the solid formed.

5. Dissolve a small quantity of lead in nitric acid and add to the solution dilute sulphuric acid. What do you consider the nature of the solid formed?

6. Pass a mixture of sulphur dioxide and oxygen through a scrubbing bottle containing strong sulphuric acid in order to dry the gases, and then through a hard glass tube containing carefully dried platinized asbestos[1] (asbestos covered with a layer of finely divided platinum). Heat the platinized asbestos strongly and pass the gaseous product into a carefully dried U-tube surrounded with a freezing mixture of ice and salt. Examine the solid which condenses in the U-tube. Dissolve a portion in a drop or two of water. What is the action of this solution on litmus and on barium hydrate solution? Decide what the solution contains and what is the nature of the white solid.

[1] This may be prepared by dipping asbestos into a solution of platinum chloride, and then into ammonium chloride solution. The asbestos must then be dried and heated to redness in a Bunsen flame.

CHAPTER XXV.

PHOSPHORUS AND SOME OF ITS COMPOUNDS.

149. Yellow Phosphorus.

CAUTION.—*Remember the precautions necessary in handling phosphorus* [Exercise 66 (*c*)].

(*a*) Remove a piece of phosphorus from the bottle and place it at once beneath the surface of water in an evaporating basin. Endeavour to cut it with a knife. Warm the water and phosphorus on a water bath to a temperature of 18° C. Can you now cut the phosphorus more easily? Describe the appearance and colour of freshly cut phosphorus.

(*b*) Continue to heat the basin and contents on the water bath, stirring the water constantly with the thermometer. Note the temperature at which the phosphorus melts.

(*c*) Cut off a second piece of phosphorus no larger than a grain of wheat. Remove it from the water and dry it rapidly with blotting paper. Place the phosphorus at once on a crucible lid which is floating on water in a suitable basin. Remove the basin to a draught cupboard and warm it gently on a water bath. Stir the water in the basin with a thermometer. Note the exact temperature at which the phosphorus catches fire.

(*d*) Place another tiny fragment of phosphorus on a crucible lid floating on water. Examine the appearance of the phosphorus in a darkened room.

(*e*) Place a tiny fragment of phosphorus in a test tube and pour over it 1 c.c. of alcohol.

CAUTION.—*Carbon disulphide is an extremely inflammable liquid. Extinguish all flames near your bench before you remove the stopper of the bottle which contains the carbon disulphide.*

Pour 1 c.c. of carbon disulphide on to a tiny piece of phosphorus in another test tube. Does phosphorus appear to be soluble in either of these liquids? Cut three narrow strips of blotting paper. Remove by means of a clean stirring rod a drop of each of these two liquids on a separate piece of blotting paper. On the third piece of blotting paper place a drop of the water in which phosphorus has been kept. Allow the pieces of blotting paper to dry in a draught cupboard. If, when they are dry, nothing has taken place, warm them very slightly. What evidence have you that phosphorus was dissolved in any of the liquids?

(*f*) Prepare a cylinder of chlorine [Exercise 111 (*d*)]. Lower into it a small piece of phosphorus in a deflagrating spoon. Note what takes place. If the reaction does not proceed at once, warm the phosphorus slightly and replace it in the chlorine. Decide what is the nature of the product formed.

150. Red Phosphorus.

(*a*) Procure some red phosphorus. Compare its appearance and colour with that of the ordinary variety.

(*b*) Float a crucible lid on the surface of oil of vitriol contained in a large evaporating basin. Place on the crucible lid about a centigram of red phosphorus. Heat the oil of vitriol, at the same time stirring it with a thermometer which is graduated to at least 300° C. Does the phosphorus melt? Does it catch fire when heated to 200° C.?

(*c*) Discover whether red phosphorus is luminous in the dark.

(*d*) Determine whether water, alcohol, or carbon disulphide will dissolve red phosphorus.

CAUTION.—*Read again the precautions to be taken in using carbon disulphide* (p. 237).

(*e*) Repeat Exercise 149 (*f*), using red phosphorus in place of yellow. Does red phosphorus catch fire when placed in chlorine? Heat the red phosphorus and discover whether by that means you can make it burn in chlorine.

(*f*) In order to compare the properties of the two varieties of phosphorus draw up a table in the following manner:

	YELLOW PHOSPHORUS.	RED PHOSPHORUS.
Form - - - -		
Colour - - - -		
Melting point - - -		
Solubility in :—		
water - - - -		
alcohol - - -		
carbon disulphide -		
Burning temperature - -		
Combination with chlorine		

151. The Common Oxide and Acids of Phosphorus.

(*a*) Dry thoroughly a bell jar and a tile, or failing the latter a sheet of glass. Place on the tile a piece of phosphorus in an inverted crucible lid or a piece of broken porcelain. Set fire to the phosphorus and cover it with the bell jar. When the fumes have settled, examine the white powder. Remove a little on a *dry* knife blade and let it fall into a few drops of water on a watch glass. What do you notice as the oxide enters the water? Leave some grains of the powder in the air for a time. What property do you find the powder possesses?

(*b*) Place a drop of the solution obtained in Exercise 151 (*a*) on litmus paper. Try if the dry powder produces the same effect on dry litmus paper.

(*c*) Dissolve in water the whole of the oxide remaining. Divide the solution into two parts. Boil one part over a low flame, until its volume is reduced to a half. Add distilled water until the solution has the same volume as it had originally, and then boil it again until its volume is reduced to a half. Meanwhile proceed with the following exercise.

(*d*) Neutralize the other part of the original acid solution with caustic soda solution. Place about 2 c.c. of the neutralized acid in a test tube and add a few drops of silver nitrate solution. To a similar quantity in another test tube add a little raw white of egg and a few drops of acetic acid. Describe exactly what takes place in each case.

(*e*) Discover whether the solution which has been boiled [Exercise 151 (*c*)] is still acid. Neutralize it with caustic soda and find also what effect a few drops of it have on silver nitrate solution and on white of egg. Does it contain the same substance as before it was boiled? Note exactly what are the differences.

(*f*) Neutralize the remainder of the boiled solution with caustic soda. Evaporate the neutralized liquid to dryness. Examine the solid thus prepared. Place it in a crucible and heat it over a Bunsen flame. Watch the bottom of the crucible carefully, shading the light from it with your hand. As soon as the solid begins to appear red hot at any point take away the flame. Allow the solid to cool in the crucible and then dissolve it in distilled water. Discover whether it has the same effect on silver nitrate solution as the solid from which it was prepared. Find also its effect on white of egg.

(*g*) Draw up a table in the following manner in order to compare the properties of the salt formed by neutralizing the original acid, the salt formed from the boiled acid, and the salt formed by heating the latter:

	SALT FROM ORIGINAL ACID.	SALT FROM THE BOILED ACID.	SALT FORMED BY HEATING THE LATTER.
Effect on :—			
silver nitrate			
white of egg			

The three substances which you have thus distinguished are all phosphates of sodium and are called sodium metaphosphate, sodium orthophosphate, and sodium pyrophosphate respectively.

(*h*) Obtain some ordinary sodium phosphate and decide which of the three phosphates of sodium it is.

UNIVERSITY OF LONDON
MATRICULATION EXAMINATION.

CHEMISTRY.

JUNE, 1905.

[*Candidates are informed that the style of the answer will in every case be taken into consideration in awarding marks. Marks will be deducted if irrelevant matter is introduced, and in no case must the length of an answer exceed* 400 *words. Chemical equations and diagrams should be given whenever these add to the clearness of the answer.*]

[SIX *questions only are to be attempted.*]

1. Describe fully two laboratory methods for preparing and collecting a small quantity of oxygen. Draw carefully the apparatus you would use for each experiment, and state, especially, how you would in each case guard against the presence in the gas of moisture, of chlorine, and of nitrogen derived from the air. How would you test a sample of the gas to assure yourself that the two latter impurities were not present?

2. What is a flame? Describe fully the actions which take place when hydrogen is burnt at a jet, and alcohol (C_2H_5OH) in a spirit lamp. Explain clearly why these flames are far less luminous than that of an ordinary candle or lamp.

3. It is stated that metals and acids frequently interact in such a way as to liberate hydrogen and form a salt of the metal. Describe two experiments in which this occurs and

two in which hydrogen is not liberated. State clearly in each case what substances are produced and the conditions under which the actions you describe take place, and give the equations which represent these actions.

4. Give clear but brief accounts of two distinct methods of preparing carbon monoxide. State its chief properties, and describe an experiment in which it combines directly with oxygen and an experiment in which it removes oxygen from a compound.

5. Describe fully the method you would employ in the laboratory to convert a small quantity of either yellow or red phosphorus into phosphoric acid. Describe the appearance and properties of the product you would obtain. How would you prepare from phosphoric acid a specimen of disodium hydrogen phosphate (Na_2HPO_4, $12H_2O$)? What is produced when this salt is strongly heated?

6. What methods, direct or indirect, would you adopt in the laboratory in order to prepare from sulphur (1) iron sulphide, (2) hydrogen sulphide, (3) sulphur dioxide, (4) sulphur trioxide? How would you proceed in order to obtain again a small quantity of sulphur from any one of these compounds?

7. Explain fully the meaning of the term "equivalent weight." 1·071 gram of tin was dissolved in strong hydrochloric acid and was found to liberate 200 c.c. of hydrogen measured at 0° and 760 mm. pressure. 1·661 gram of an oxide of tin left after reduction 1·309 gram of the metal. From each of these results calculate the equivalent of tin. Compare the two values obtained and state briefly what you think may be learnt from them. (1 litre of hydrogen at 0° and 760 mm. pressure weighs 0·09 gram.)

8. What reasons have we for stating that in two volumes of hydrogen chloride, measured at any given temperature and pressure, there are contained quantities of hydrogen and of chlorine which, if in the free state and at the same

temperature and pressure, would each occupy one volume? Describe as fully as you can the actual experiments on which your statements are based.

SEPTEMBER, 1905.

[SIX *questions only are to be attempted.*]

1. Describe any two simple experiments which may be carried out in the laboratory and which illustrate the following statement:

> "However any given chemical compound is prepared, it is always found to be composed of the same elements combined in the same proportions."

2. Describe experiments which show that calcium carbonate contains the element carbon.

Ten grams of marble were placed in 100 c.c. of a warm solution of hydrogen chloride in water. When action had entirely ceased the residue of marble was removed and dried. It was then found to weigh 6 grams. From these data calculate the concentration of the acid in grams of hydrogen chloride per litre. $Ca = 40$. $Cl = 35{\cdot}5$.

3. How are the two oxides of hydrogen prepared? What is the effect of heating each of them? Describe two experiments which illustrate the difference in chemical behaviour of these two substances.

4. Write full accounts of any two experiments you may have seen or made which show that when a solid has been dissolved it is not always possible to recover the solid unchanged by evaporating the solution.

Explain clearly the reason for this in each of the two cases you select.

5. What is the chemical nature of "washing soda"? How would you prepare a small quantity of washing soda from a solution of caustic soda ($NaOH$)?

What reactions occur when you add the following substances to washing soda dissolved in water:—(*a*) hydrogen acetate, (*b*) slaked lime?

6. Describe clearly two experiments which illustrate the use made, in the laboratory, of the physical properties of substances—(*a*) for identifying substances, (*b*) for preparing substances in a pure state.

7. The gas produced by burning 0·48 gram of sulphur in a large excess of oxygen was passed first over finely divided platinum at a red heat and then into 100 grams of a 3 per cent. solution of sodium carbonate in water.

Give equations representing the changes which occurred in the above experiment, and calculate what weight of solid was left when the resulting liquid was evaporated to dryness and the residue heated strongly. Na = 23. S = 32.

8. From what sources and in what manner is acetic acid prepared? How would you proceed in order to show that acetic acid contains carbon and hydrogen but no nitrogen?

JANUARY, 1906.

[Six *questions only are to be attempted.*]

1. How would you prepare and collect a jar of chlorine dry and free from any considerable proportion of air? Draw and describe the apparatus you would use, and explain why you cannot collect this gas over quicksilver and how you would test a jar of the gas in order to detect in it the presence of air.

2. What two gaseous compounds can be obtained from ammonium chloride? How would you prepare and collect a quantity of each of them? Draw the apparatus you would use in each case, and give the reactions which occur.

3. Mention three common substances which give off oxygen when they are heated, and state what other substances are produced together with the oxygen.

Explain how you would find, experimentally, the exact volume of oxygen given off by a gram of any one of these substances, drawing a figure of the apparatus you would employ for collecting and measuring the gas.

4. Describe exactly how you would prepare some nitric acid from sodium nitrate. If you desired to obtain 20 grams of the acid, what quantity of each of the necessary materials would you take? Na = 23.

5. Write a short account of some experiments with phosphorus which lead to the conclusions (*a*) that phosphorus is not a metal, (*b*) that this element exists in two distinct forms.

6. How would you discover experimentally the volume of steam produced by the union of 100 c.cs. of hydrogen with 50 c.cs. of oxygen? Describe and draw carefully the apparatus you would use and state clearly how you would carry out the experiment.

7. When 0·4122 gram of a certain metal was heated in a current of chlorine until the metal would combine with no more of the gas the weight of the product was found to be 0·6249 gram. Draw the apparatus you would employ in making this experiment. Explain how you would know when the absorption of chlorine was complete, and calculate how much of the metal in question would be required to replace one gram of hydrogen. Cl = 35·45.

8. What actions take place (1) when magnesium is burnt in air and the product subsequently dissolved in hydrochloric acid, (2) when sodium is thrown upon water, and the liquid subsequently neutralized with oxalic acid, (3) when chalk is strongly heated and the residue subsequently exposed to the air for several weeks?

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